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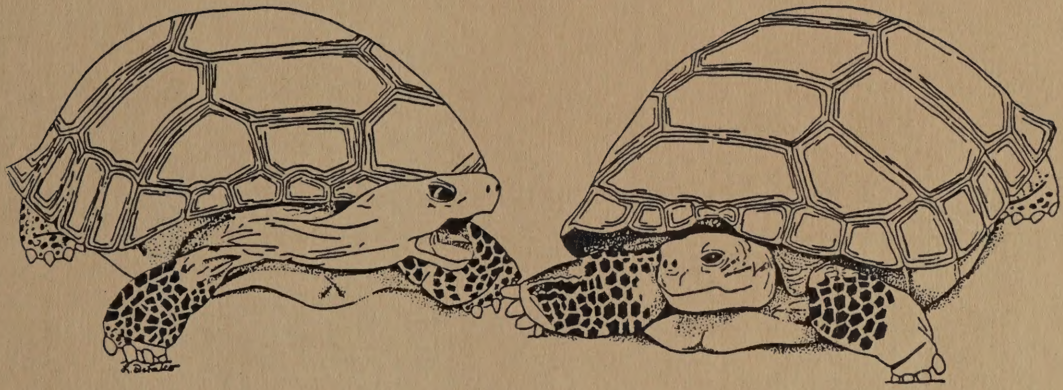
FY1989 Annual Report



By

Todd C. Esque, R. Bruce Bury and Lesley A. DeFalco

Prepared for:

USDI Bureau of Land Management

Cedar City District, Utah

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Nutrition and Foraging Ecology of the Desert Tortoise:

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Todd C. Esque, R. Bruce Bury and Lesley A. DeFalco

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National Ecology Research Center
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1.0 INTRODUCTION

The desert tortoise is listed as a Threatened Species north and west of the Colorado River (Federal Register- April 2, 1990). This action was based primarily on a rapid decline in tortoise populations in California due to the occurrence of a disease known to infect the upper respiratory tract of the desert tortoise. Information in the federal register and from several tortoise experts have suggested that this disease could be triggered by malnutrition in wild populations, but this is still a hypothesis that requires testing.

Similar to other wildlife species, the traditional means of analyzing food habits of desert tortoises included collecting specimens and dissecting them to acquire samples of gut contents (Ortenburger and Ortenburger 1927, Bailey 1928 in Grover 1989, Woodbury and Hardy 1948). Although still useful opportunistically (e. g. using previously killed tortoises as encountered), the practice of sacrificing tortoises for food habits is not possible as populations are now protected. Probably the most commonly used technique for learning about food habits of desert tortoises is simply watching what they eat. Almost every field researcher that has studied desert tortoise ecology has made note of food plants or feeding behavior (Woodbury and Hardy 1948, Burge and Bradley 1976, Schneider 1980, Hohman and Ohmart 1980, Minden and Keller 1981, Luckenbach1982, Nagy and Medica 1986). This has resulted in lists of food plants from many locations. However, many of these studies were designed to solve questions other than those on diet and nutrition. Therefore, analyses of such data were descriptive. Hansen et al. (1976) pioneered the use of microhistological analysis of tortoise scat to identify foods eaten by desert tortoises, and other researchers have followed this technique (Coombs 1979, Hohman and Ohmart 1980, Minden and Keller 1981).

The purpose of this study is to provide baseline information on tortoise foraging behavior, nutrition, and habitat quality in southwestern Utah. This research has been designed to answer questions and develop technologies that may be used throughout the range of the desert tortoise. In some instances, we have borrowed techniques routinely used for other wildlife species. In contrast, we are also experimenting with state-of-the-art technologies and their application in new areas of tortoise research.

We have proposed an integrative research project that will include three components: field work, laboratory experiments and a modelling effort. Information

is provided on the ecology and behavior of wild tortoises and their use of habitat. We present results of tortoise research, including techniques for assessing tortoise utilization of food plants, and of habitat analyses.

We focused on three questions:

- What techniques are most useful for determining desert tortoise diet and foraging behavior?
- What do desert tortoises consume in relation to what is available to them?
- Do tortoises choose the most nutritious items available to them?

Our research has been aligned closely with the studies being conducted with the Arizona Department of Game and Fish on their pilot study " Health of Desert Tortoises." This cooperative research is expected to strengthen the results of both studies. Also, we are working in cooperation with the Utah Division of Wildlife Resources (UDWR) on their study which focuses on reproductive behavior of free-ranging desert tortoises on the Beaver Dam Slope, Utah.

2.0 STUDY AREA

The study area is in Washington County, Utah in the southwestern corner of the state (Fig. 1). This area is at the northern and eastern geographical limits of the Mojave desertscrub biome (Turner 1982). Within the range of the desert tortoise, this area is also in the extreme northeast corner of the geographic range of the species (Patterson 1982). The City Creek Study Plot is ~25 miles northeast of the Beaver Dam Slope. It has been generally assumed that tortoises living in the Dixie Valley, where the City Creek plot is located, are completely isolated from individuals on the Beaver Dam Slope. But we reviewed BLM and State distribution data for the desert tortoise, and it is apparent that tortoise transect surveys are not complete. Locality records now exist for tortoises close to either side of Motoqua Pass, which is likely a dispersal route over the Beaver Dam Mountains. Animals inhabiting the Beaver Dam Slope are probably part of the greater Moapa Valley population which extends into southern Nevada (clustered halfway between Las Vegas and Mesquite, Nevada) and south into northwestern Arizona (Bury et al.1988) .

2.1 City Creek Study Plot (Figure 2)

The City Creek Study Plot (CC plot) is 4 kilometers (2.5 mi) north of the town of St. George, Utah. A population survey of the City Creek plot was conducted in 1988 (Coffeen et al. 1989). Field workers located and marked tortoises, and collected tortoise mortalities (mostly shells). Over 230 individual tortoises were marked on the one-square mile plot. This is a high population density in conjunction with a population structure representing tortoises of all size classes. Besides the thriving tortoise population, the area supports a host of other wildlife including: nesting turkey vulture (*Cathartes aura*), mountain lion (*Felis concolor*), sidewinder rattlesnake (*Crotalus cerastes*) and gila monster (*Heloderma suspectum*). The City Creek Plot is a unique ecosystem in proximity to an expanding municipality.

Hardy (1945) stated, "The distribution of the desert tortoise (*Gopherus agassizii*) presents a situation similar to that of the Joshua tree as it naturally occurs only west of the Beaver Dam Mountains. Individuals released in the desert regions near Saint George, however, have been able to survive for at least a few years." Dr. Hardy did not support his comment on the introduction of tortoises with data. We find it difficult to understand how tortoises should be absent from the Dixie Valley when other desert dwellers such as the gila monster and sidewinder rattlesnake,

(which are frequently found in association with tortoises in other parts of their range), are resident in the Dixie Valley. Certainly the

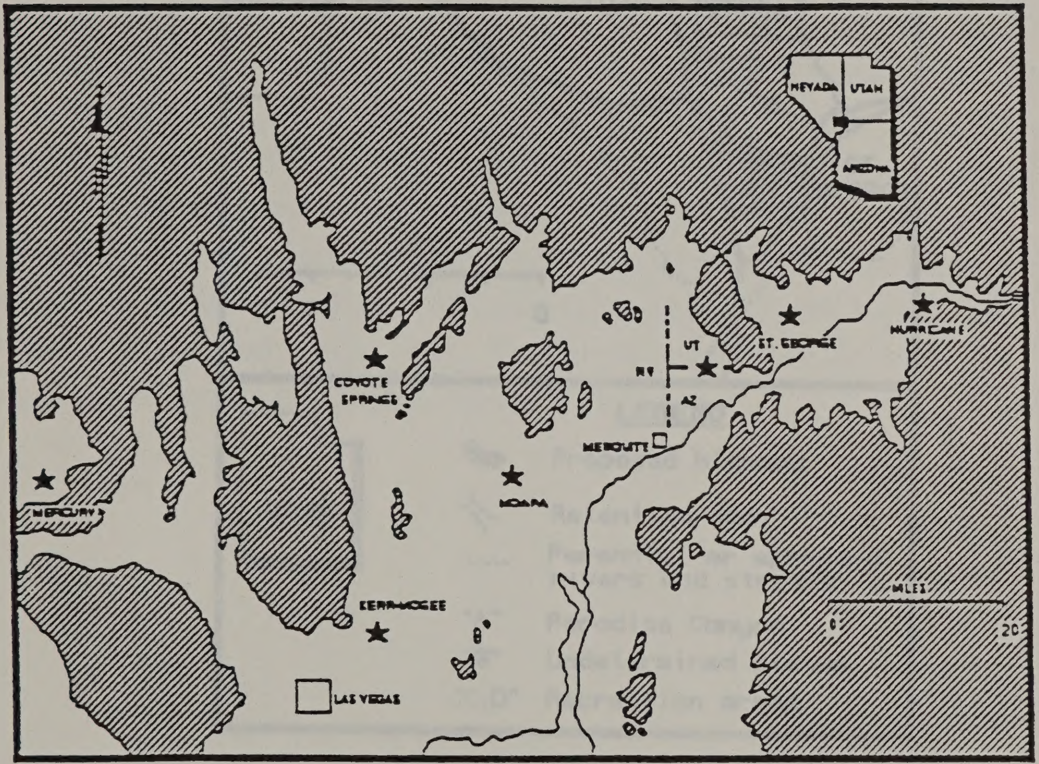


Fig. 1: Northeast Mojave Desert Study Areas

ELEVATION

▨ Above 1220 m

☐ Below 1220 m

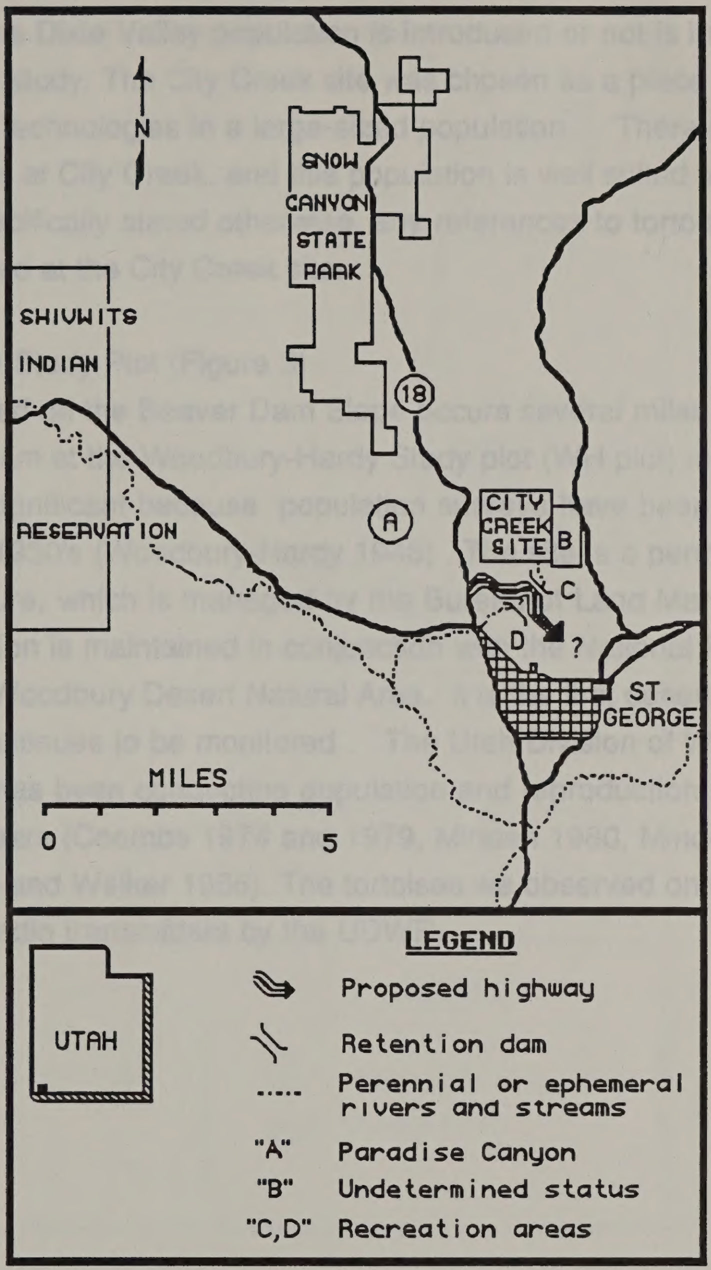


Fig. 2: St. George, Utah Regional Map including City Creek Study Plot.

pioneers of St. George did not encourage the establishment of venomous reptiles in the Dixie Valley. We and others earlier documented the tortoise as a native species in the Dixie Valley (see Bury et al. 1988).

Ultimately, whether the Dixie Valley population is introduced or not is irrelevant to the objectives for this study. The City Creek site was chosen as a place to experiment with new technologies in a large-sized population . There is a healthy population of tortoises at City Creek, and this population is well suited for our purposes. Unless specifically stated otherwise, any references to tortoise ecology refer to work completed at the City Creek site.

2.2 Woodbury-Hardy Study Plot (Figure 3)

The study plot we used on the Beaver Dam Slope occurs several miles northeast of the town of Beaver Dam at the Woodbury-Hardy Study plot (WH plot) in Utah, which is historically significant because population surveys have been conducted at this site since the 1930's (Woodbury-Hardy 1948) . The site is a permanent cattle-grazing exclosure, which is managed by the Bureau of Land Management (BLM) - Utah. A portion is maintained in conjunction with the National Park Service and is known as the Woodbury Desert Natural Area. It is the first desert tortoise research area and continues to be monitored . The Utah Division of Wildlife Resources (UDWR) has been conducting population and reproduction studies on the site for several years (Coombs 1974 and 1979, Minden 1980, Minden and Keller 1981, Coffeen and Welker 1986). The tortoises we observed on the WH site were equipped with radio transmitters by the UDWR.

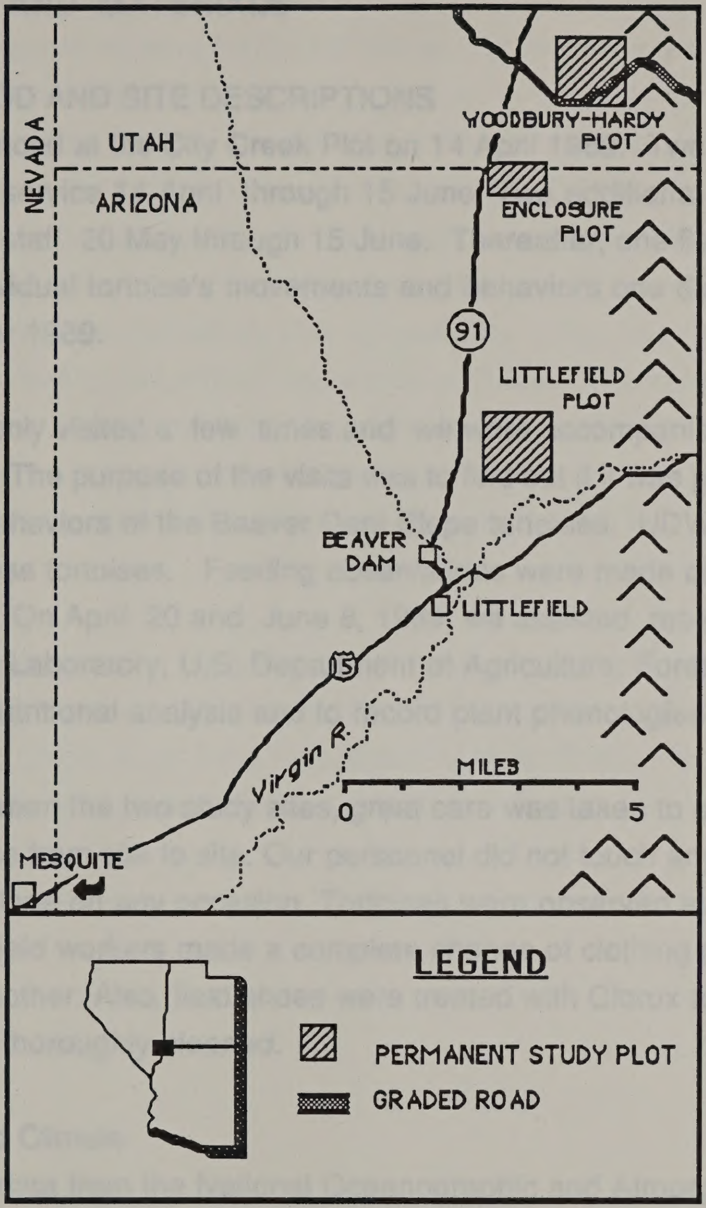


Fig. 3: Beaver Dam Slope Regional Map including Woodbury-Hardy Plot, Utah and Littlefield Plot, Arizona.

3.0 METHODS AND MATERIALS

3.1 STUDY PERIOD AND SITE DESCRIPTIONS

Field work commenced at the City Creek Plot on 14 April 1989. Two field personnel were in service 14 April through 15 June. Two additional field personnel were added to the staff 20 May through 15 June. Thereafter, one field person monitored the individual tortoise's movements and behaviors one day per week through September 1989.

The WH plot was only visited a few times and we were accompanied by UDWR staff on each visit. The purpose of the visits was to find out if it was possible to observe feeding behaviors of the Beaver Dam Slope tortoises. UDWR is studying reproduction of these tortoises. Feeding observations were made at the WH plot on 6-7 June 1989. On April 20 and June 8, 1989, we assisted researchers from the Shrub Science Laboratory, U.S. Department of Agriculture, Forest Service, to collect plants for nutritional analysis and to record plant phenologies .

When moving between the two study sites, great care was taken to avoid transmitting disease from site to site. Our personnel did not touch any tortoises on the Beaver Dam Slope on any occasion. Tortoises were observed at a distance over 10 meters. Field workers made a complete change of clothing prior to moving from one site to another. Also, field shoes were treated with Clorox and vehicles were washed and thoroughly cleaned.

3.1.1 Weather and Climate

We used weather data from the National Oceanographic and Atmospheric Administration (NOAA) to compare monthly precipitation and temperature trends. For the CC plot, we used data from the weather station at the St. George Municipal Airport, which is ~7 km (4.5 miles) due south. St. George data include precipitation, ambient temperature, and ground temperatures. The closest NOAA station for the WH plot is ~ 15 km (9 miles) south in the town of Beaver Dam, Arizona (Figure 3). Ground-surface temperatures were not available at the Beaver Dam station.

3.1.2 Habitat Descriptions - CC plot

In 1989, field personnel working for the UDWR and BLM created a permanent grid across the one-square mile study plot using reinforcing-bar with metal identification tags. Each quadrat within the grid was 1/100th of one square mile (Fig. 4). We adapted a habitat map for the City Creek site from BLM - UDWR work (Coffeen et al.,1989). This previous map stratified the site into three patch types using soil substrate (particle size and geomorphology) as criteria to delineate habitat patches: Dune, Rocky and Transition. Our revised map takes into account geomorphology as well as vegetation associations. These criteria have refined habitat classifications into four major groups: Dune, Rocky, Rocky Transition and Transition. We used a computer graphics tabulator on our habitat map to calculate the size and number of individual patches of habitat at the CC plot.

3.1.3 WH plot

The Woodbury-Hardy site has been described by several researchers (Hardy 1945, Woodbury and Hardy 1948, Minden and Keller 1981). Recently, soil surveys of the Beaver Dam Slope, Utah were completed by BLM. That area has been characterized as having a great diversity of soil types present (John Payne, pers. comm.).

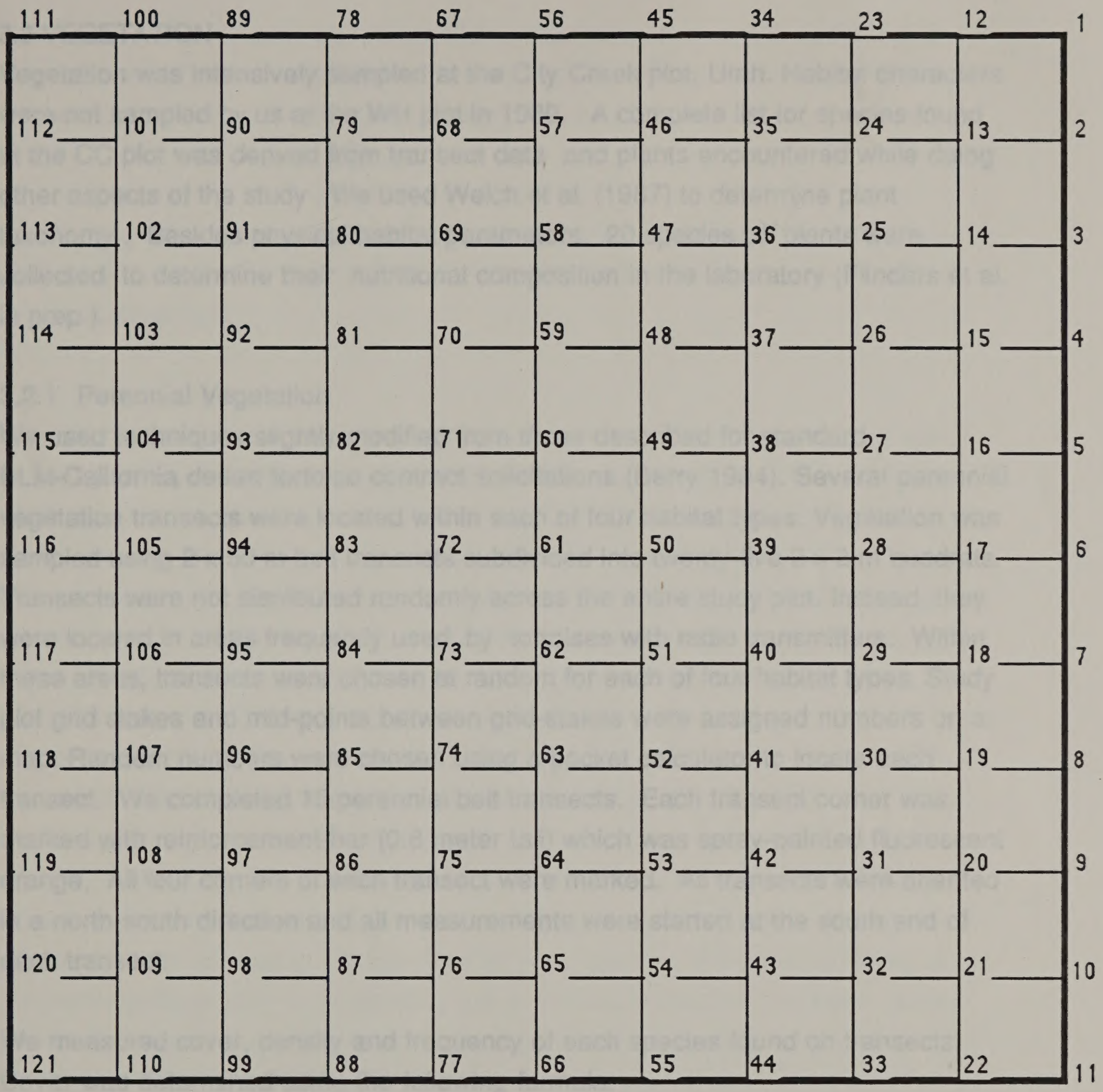


Fig. 4: One-tenth mile markers on the City Creek Study Plot.

3.2 VEGETATION

Vegetation was intensively sampled at the City Creek plot, Utah. Habitat characters were not sampled by us at the WH plot in 1989. A complete list for species found at the CC plot was derived from transect data and plants encountered while doing other aspects of the study . We used Welch et al. (1987) to determine plant taxonomy . Besides physical habitat parameters, 20 species of plants were collected to determine their nutritional composition in the laboratory (Flinders et al. in prep.).

3.2.1 Perennial Vegetation

We used techniques slightly modified from those described for standard BLM-California desert tortoise contract solicitations (Berry 1984). Several perennial vegetation transects were located within each of four habitat types. Vegetation was sampled using 2 x 50 m belt transects subdivided into twenty-five 2 x 2 m quadrats. Transects were not distributed randomly across the entire study plot. Instead, they were located in areas frequently used by tortoises with radio transmitters. Within these areas, transects were chosen at random for each of four habitat types. Study plot grid stakes and mid-points between grid-stakes were assigned numbers on a map. Random numbers were chosen using a pocket calculator to locate each transect. We completed 15 perennial belt transects. Each transect corner was marked with reinforcement-bar (0.6 meter tall) which was spray-painted fluorescent orange. All four corners of each transect were marked. All transects were oriented in a north-south direction and all measurements were started at the south end of each transect.

We measured cover, density and frequency of each species found on transects. Cover was determined using the following formula:

$$C = \pi a \ b,$$

where C = cover of an individual shrub, a = the minimum diameter of a given shrub, and b = the maximum diameter for the same shrub. We also included a calculation for species volume and criteria for occurrence of plant specimens on the edges following descriptions in California BLM contracts (Berry 1984). Observations of perennial phenology were collected for key plant species previously known to be eaten by desert tortoises.

A similarity index (Turner and Berry 1984) was calculated for the species compositions of perennial plants for each habitat type from the results of perennial transect data. The similarity index was calculated :

$$S = \frac{C}{A + B},$$

where C is the number of species common to both habitat types, A is the number of species found in the first habitat, and B is the number of species found in the second habitat type.

3.2.2 Annual Vegetation

Shrubby forbes that die back to the ground and winter or summer annuals were included as annual vegetation. Quadrat size was determined by trial and error. First, several test plots were established on 20 x 50 cm quadrats. The majority of these quadrats did not have any annual vegetation growing on them and therefore were of inadequate size. We rejected these small quadrats as a means to sample annual plants in 1989. Instead, a quadrat of one square meter was of adequate size to record plants on most quadrats. Our quadrats were measured with a collapsible, wooden frame. Quadrat locations were chosen at random within each of four habitat types across the entire City Creek Study Plot, and they were oriented in a position square with compass cardinal points. We calculated cover, biomass, density and frequency for each species. Cover was visually estimated in square centimeters. We counted plants individually for density. We collected above ground biomass and air-dried samples for measurements of primary production. We calculated frequencies for each species. We collected data for annual vegetation prior to conducting any perennial vegetation transects (except phenology data on perennials) since dry conditions led to early senescence of annuals in 1989. Approximately 40 quadrats were placed in each of four habitat types, and we collected data from 26 April to 4 June 1989.

3.2.3 Additional Habitat Parameters

In addition to collecting data on the vegetation and soils at the CC plot, we recorded data on water catchments, denning localities, areas of maximum productivity of annual vegetation, and areas of intense tortoise activity, including sites of osteophagy, geophagy and lithophagy (bone, soil and rock ingestion, respectively). Specific environmental conditions recorded on data forms include: habitat type, vegetative association, percent slope, aspect, percent cloud cover,

approximate wind speed using the Beaufort scale, ambient temperature, temperature 1 cm above ground, and ground temperature.

3.3 RADIO-TRACKING TORTOISES

We radio-equipped 10 female tortoises of breeding size (>200 mm Maximum Carapace Length - MCL). At the CC plot, we searched parts of the study plot which were known to be concentration areas for tortoises (Coffeen et al. 1989). We systematically walked across the plot and used the first 10 adult female tortoises which were encountered. Prior to being radioed the tortoises were weighed and measured. Photographs (35-mm slides) were taken of the carapace of each tortoise. Data were collected on standard data cards and will remain on permanent record at the UDWR. Observations on health included monitoring tortoises for signs of the Upper Respiratory Disease Syndrome (URDS) . If not already permanently marked with a number by the UDWR, we marked each animal according to methods described by Berry (1984). The numbers we assigned to individuals were provided on pre-numbered data sheets by the UDWR.

Tortoises were located by a radio receiver with a hand-held, three-element yagi-antenna. We used two-stage transmitters with AA-3 volt batteries (predicted to last 15 months) and 170 mm long nickel antennas on the desert tortoises . The transmitter and battery were packaged in dental acrylic. Each package (minus epoxy with which it was attached to each tortoise) weighed ~30g. Antennas were coated with heat-shrink plastic tubing to protect them from abrasion. The radio packages were mounted anteriorly on the tortoises with five-minute epoxy which was molded to contour the tortoise shells using a masking-tape mold . Radio antennas were mounted in such a way to cover the least number of scute sutures. Also, transmitters were located anteriorly just above the third and fourth left marginal scutes (Fig. 5). We designed the transmitter package to minimize interference with the tortoise. The transmitters were placed on the anterior part of the carapace to allow the tortoises to maneuver during copulation. Also, the transmitter height is less than that of the shell, which reduces possible entanglement on branches or ledges. We will replace radio packages at the advent of the 1990 field-season, and we will remove them at the conclusion of the study.

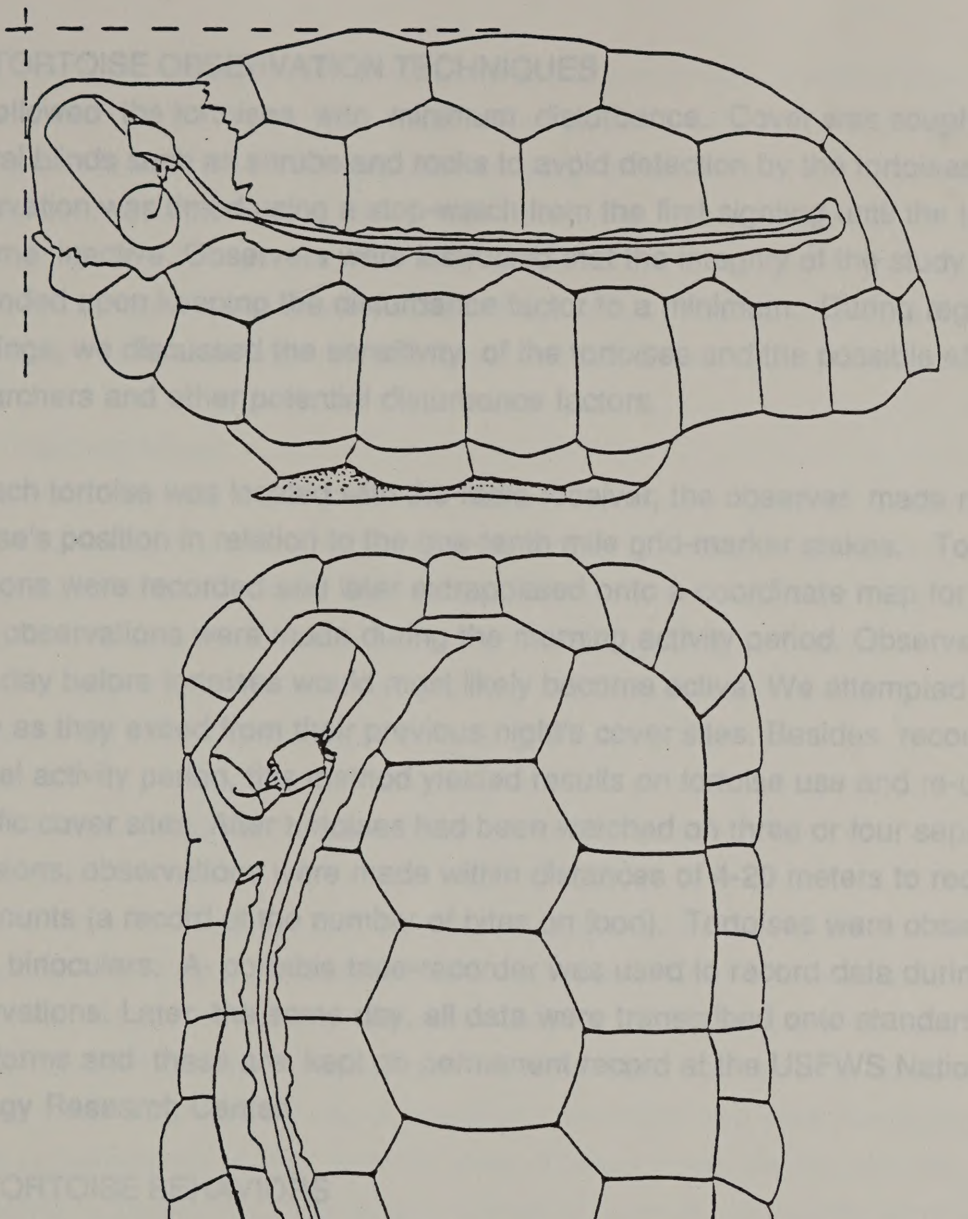


Figure 5: Lateral and dorsal views of tortoise equipped with radio-transmitter

Tortoises which had already been radioed by UDWR personnel were observed at the WH plot. It was our policy not to handle tortoises after the initial radio installation work at City Creek nor any of those on the Beaver Dam Slope.

3.4 TORTOISE OBSERVATION TECHNIQUES

We followed the tortoises with minimum disturbance. Cover was sought behind natural blinds such as shrubs and rocks to avoid detection by the tortoises. Each observation was timed using a stop-watch from the first sighting until the tortoise became inactive. Observers were instructed that the integrity of the study depended upon keeping the disturbance factor to a minimum. During regular staff meetings, we discussed the sensitivity of the tortoises and the possible effects of researchers and other potential disturbance factors.

As each tortoise was located with the radio receiver, the observer made note of the tortoise's position in relation to the one-tenth mile grid-marker stakes. Tortoise locations were recorded and later extrapolated onto a coordinate map for analysis. Most observations were made during the morning activity period. Observers started each day before tortoises would most likely become active. We attempted to be ready as they exited from their previous night's cover sites. Besides recording the full diel activity period, this method yielded results on tortoise use and re-use of specific cover sites. After tortoises had been watched on three or four separate occasions, observations were made within distances of 4-20 meters to record their bite counts (a record of the number of bites on food). Tortoises were observed using binoculars. A portable tape-recorder was used to record data during field observations. Later the same day, all data were transcribed onto standardized data forms and these are kept on permanent record at the USFWS National Ecology Research Center.

3.5 TORTOISE BEHAVIORS

We recorded a running account of tortoise behaviors on portable tape-recorders. On several occasions we used a video-camera to record tortoise behaviors. Foraging data included: habitat types which were used, amounts of time feeding, species consumed, and number of bites consumed per plant or species. Also, observations were made on sources of disturbance and responses to disturbances, cover site use, relative foraging efficiency in adults and juveniles, and agonistic behaviors between tortoises.

Bite count techniques have been used successfully in forage studies with large herbivores (Wallmo and Neff 1970 in Korschgen 1980, Oldemeyer and Woodis 1983) and also for smaller birds and mammals (Dalke 1942, Wilson and Vaughn

1944, both in Korschgen 1980). Recording bite counts was a central theme to our field work in 1989. The bite-count technique involves watching a focal animal closely and carefully, recording details of foraging behavior. For instance, a tortoise was observed and for every bite taken, the food species and condition was recorded. During this study, notes were taken in such a way as to record each time the study animal moved to a new plant. Such close observation also allowed an estimation of bite size, and we estimated biomass consumed at a later date.

3.5.1 Feeding Rates

The feeding rate was the number of grams consumed by an adult female tortoise during the spring activity period at City Creek plot in 1989. Body mass for an average adult female tortoise was calculated from the mean body mass for the ten tortoises. We calculated feeding rates by extracting data from tortoise observations in which there was some feeding behavior. We calculated the number of grams consumed by this theoretical tortoise using the equation:

$$\text{Number of grams consumed per season} = a \times b \times c \times d \,,$$

where *a*, the mean number of grams per bite (mean # g / bite) calculated by measuring the mean dry mass of 20 *Bromus rubens* seed heads and dividing by two (consuming a *B. rubens* seed head required two bites based on field observations); *b*, the mean number of bites per hour estimated by calculating the number of bites per hour for each feeding observation and then averaging all feeding observations; *c*, the mean number of hours spent feeding per day calculated by determining the mean number of hours for all feeding observations; and *d*, the feeding season duration determined by tortoise activity.

3.5.2 Home Range

We plotted home ranges of individual tortoises on a grid map for analysis. Home range size of each radioed tortoise was determined using the non-circular home range method (Jennrich and Turner 1968). We used this method instead of the minimum polygon method because we were more concerned with an accurate representation of the tortoise's home range than an estimate. We performed two calculations of home range. First, we recorded the home range for each tortoise at City Creek considering all location points for each animal as one set of data. Secondly, for individual tortoises that had two well-defined centers of activity

which they moved between, it was necessary to calculate one home range that was inclusive of all points and another home range dividing up the activity areas. Locality data were also used to analyze the amount of time individual tortoises spent in different habitat types.

3.6 HEALTH

In light of recent emphasis on disease in wild tortoise populations, we recorded presence or absence of known signs of ill health. Throughout the 1989 field season, we visually examined both the radioed tortoises and the non-radioed tortoises for external signs of illness. We looked for viscous exudate from the nose and/or abnormally watery eyes.

3.7 MICROHISTOLOGICAL ANALYSIS

We collected samples of fresh scats on the study plot for microhistological analysis following the technique of Hansen et al. (1976). Fresh scats were collected away from caves or burrows to ensure that they were excreted during the current field season. Collections were made if scat was black, slightly moist, and when they appeared to have no wear from age. These suggest recent deposition (Luckenbach,1982). Collected scats were placed in separate envelopes on which we recorded date, location and identification of tortoise. These specimens were allowed to air dry, then placed into a freezer to inhibit the destruction of scats by fungus or arthropods. Scat samples were divided into two arbitrary time periods according to when they were found. Fifteen samples were drawn at random from each time period for microhistological analysis. Thirteen scats from radioed tortoises were sampled. Five samples were drawn from gastrointestinal tracts of dead tortoise specimens from known localities. One-half of each scat was used for the microhistological sample. The other one-half was saved for future analysis. Samples were prepared for microhistological analysis as described in Hansen et al. (1976).

3.8 NUTRITIONAL CONTENT OF VEGETATION

Personnel from the Shrub Sciences Laboratory, Intermountain Research Station, U.S. Forest Service were contracted by BLM to collect plant specimens and conduct laboratory analyses on plants used as food species by the tortoise. We provide guidance on which species to collect and to help collect samples. We accompanied the Forest Service personnel on all collecting trips. Collecting

occurred on three separate occasions. The purpose of each trip was to collect specimens for nutritional assay at three tortoise study sites: the City Creek plot and Woodbury-Hardy plots in Utah, and the Littlefield plot in Arizona (Figs. 2,3). We collected twenty species at each site. We selected these species from items known as tortoise food in the tortoise literature (Hohman and Ohmart 1980, Duck and Pregler 1986), and we collected the same twenty species at each site. Also, we collected a few species which were important at each site. Sample size was large enough to separate out plant parts for those species which are known to be consumed preferentially by tortoises. Techniques for laboratory analyses are found in a separate Forest Service report (Flinders, McArthur, and Sanderson, in prep.).

3.9 METHODS FOR SAMPLING TORTOISE DIETS

One of our research objectives was to determine the best method of obtaining information on the diet of the desert tortoise. We considered it important to investigate any possible technique for acquiring this information, without causing harm to tortoises.

As alternative methods, we employed the use of various arthroscopes, bronchoscopes, and fiberscopes during preliminary laboratory studies in an effort to determine diet in wild desert tortoises. For the safety of the animals we used, we first investigated the anatomy of tortoises. All of our efforts were overseen by medical and veterinary professionals considered to be experts in the field of wildlife care and fiberoptic techniques.

3.9.1 Morphology of Gastrointenstinal Tract

Specimens of dead tortoises were obtained from the UDWR. These specimens were transported on dry ice within sealed coolers from Cedar City, Utah, to Fort Collins, Colorado. Specimens were dissected by Dr. Howard Martin, D.V.M., in the necropsy laboratory of the Veterinary Teaching Hospital, Colorado State University. We collected samples of gastrointestinal tracts (GI tracts), and food items from the intact portions of those tortoises and preserved them in 70% ethyl alcohol. GI tract specimens were photographed in the laboratory using light

sources which were conducive to photographic quality on Ektachrome film. Bone and scute material were saved and are being prepared for return to the UDWR as specified in the permit.

3.9.2 A Non-DestructiveSampling Technique

Traditionally, sampling gut contents of vertebrate animals has been accomplished by sacrificing the animals and extracting the stomach (Korschgen 1980). More recently, other methods of sampling stomach contents have been developed and used on salamanders, birds, aquatic turtles (Legler 1977, Parmenter 1978) and lizards. Most of these methods incorporate the use of a gavage tube (tube inserted into the stomach) and either flushing out the stomach and collecting the contents, or withdrawing a sample with the gavage tube. Others have tried the use of a sampling device on desert tortoises through a piece of glass tube that was inserted into the tortoise stomach, but this rigid equipment did not provide adequate samples (P. A. Medica, pers. comm.). We experimented with gavage tubes, rigid arthroscopes and bronchoscopes, and a flexible fiberoptic ureterscopes. Since the use of such equipment was experimental, we will report the methods we developed in the results section.

4.0 RESULTS

4.1 WEATHER AND CLIMATE

The monthly mean maximum and minimum temperatures on the Beaver Dam and City Creek generally are similar year round (Fig. 6). However, the mean monthly summer and winter temperatures were higher at Beaver Dam than in St. George in 1988 and 1989 .

Between 1959 and 1979, precipitation was slightly greater at Beaver Dam in summer, whereas St. George received greater winter precipitation (Turner 1982). During the study period (April - June 1989), our results show that St. George and Beaver Dam received similar amounts of precipitation (Fig. 7). However, winter (October 1988 to March 1989) and summer (July 1989 to October 1989) precipitation at Beaver Dam were greater than at St. George in 1988-1989. On 16 May 1989, there was one brief period of rain showers at the City Creek plot and on the Beaver Dam Slope. At City Creek, the showers resulted in negligible runoff. Very small amounts of free-water occurred at two depressions in rock on the CC plot. They persisted for about three days during cool temperatures. Two days after the shower, sandy soils were visibly moist at depths between 2.75 cm and 15 cm. Monthly mean soil temperatures were available for only St. George, Utah (Fig. 8).

4.2 STUDY SITE DESCRIPTIONS

4.2.1 City Creek Plot

Dr. Ross Hardy (1945) first described habitats along City Creek, just down-canyon from the CC plot. He used four 60 x 60 ft. quadrats to describe frequencies and sizes of plants. Although his sample size was inadequate to generate confidence intervals for comparison to this study, he distinguished habitat patches similar to those described in this study. From a human perspective, the CC plot is unlike most tortoise habitat in the Mojave Desert . It is broken and rugged terrain as are many tortoise sites in the Sonoran desert, Arizona, but it lacks the topographic relief which characterizes many of those sites (Schneider 1980). The CC plot is characterized by deep canyons, sheer cliffs, and sand dunes. The elevational range at City Creek is 975m - 1067m (3200 to 3500 feet). The parent material is Navajo sandstone, which is easily weathered and forms extensive pink sand dunes in depressions between rocky

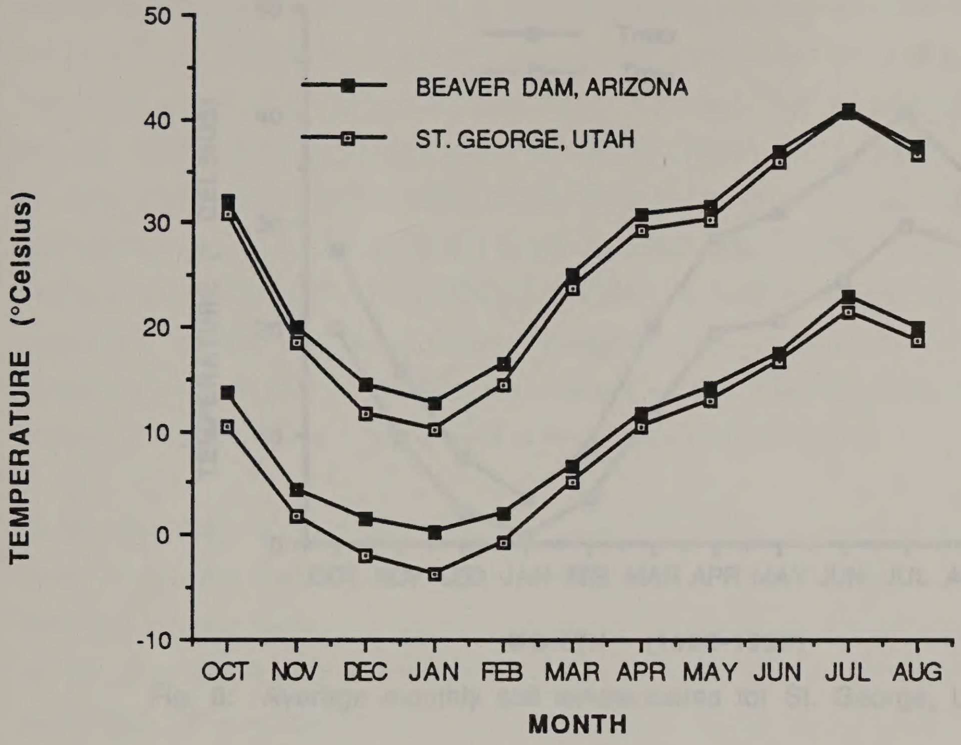


Fig. 6: Comparison of average monthly maximum and minimum temperatures at St. George, Utah and Beaver Dam, Arizona in 1988 and 1989.

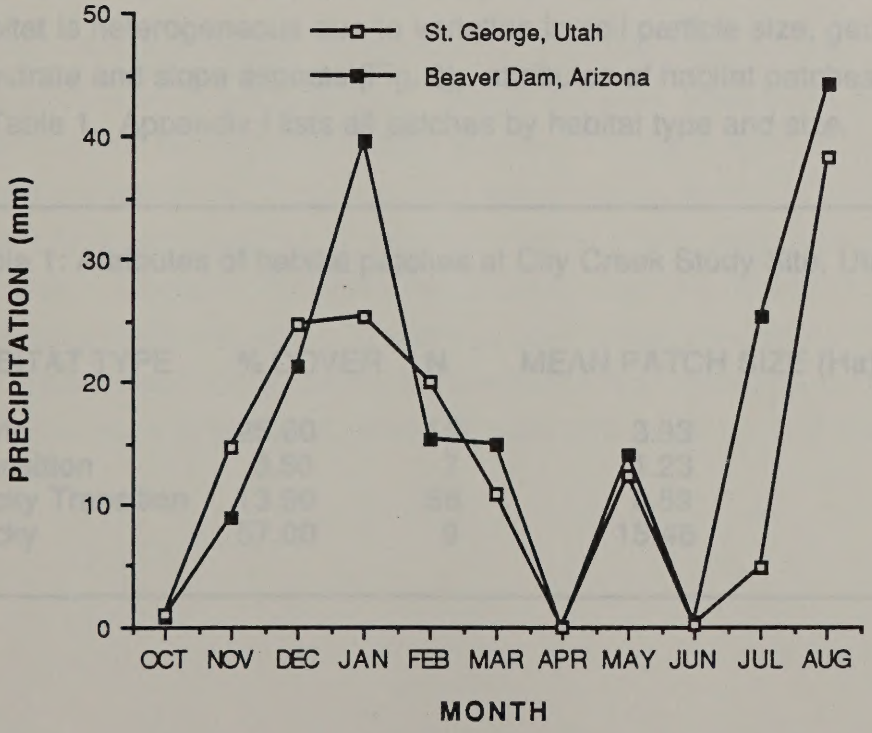


Fig. 7: Comparison of precipitation data from St. George, Utah and Beaver Dam, Arizona for 1988 and 1989.

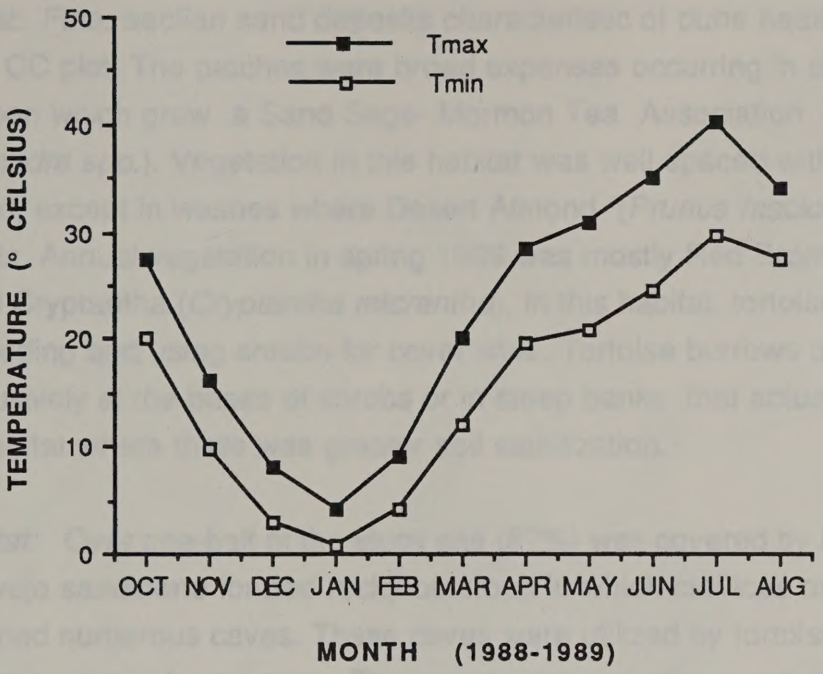


Fig. 8: Average monthly soil temperatures for St. George, Utah (1988-1989).

outcrops. Numerous solution pockets, caves and deep fissures provide cover sites for wildlife. The effects of volcanism have also shaped the site. There are basalt caps all around the study plot, but very little basalt occurs on the site itself. The habitat is heterogeneous due to variation in soil particle size, geomorphology of the substrate and slope aspects (Fig. 9), attributes of habitat patches - types are given in Table 1. Appendix I lists all patches by habitat type and size.

Table 1: Attributes of habitat patches at City Creek Study Site, Utah in 1989.

HABITAT TYPE	% COVER	N	MEAN PATCH SIZE (Ha)	RANGE (Ha)
Dune	25.60	18	3.93	0.29 - 25.12
Transition	3.50	7	1.23	.39 - 2.71
Rocky Transition	13.90	58	0.59	.0091 - 8.21
Rocky	57.00	9	15.48	.037 - 66.10

Dune habitat: Fine, aeolian sand deposits characteristic of dune habitat covered 26 % of the CC plot. The patches were broad expanses occurring in depressions or "hollows" upon which grew a Sand Sage- Mormon Tea Association (*Artemesia filifolia - Ephedra spp.*). Vegetation in this habitat was well spaced with large areas of open sand, except in washes where Desert Almond (*Prunus fasciculata*) formed dense stands. Annual vegetation in spring 1989 was mostly Red Brome (*Bromus rubens*) and Cryptantha (*Cryptantha micrantha*). In this habitat, tortoises were observed feeding and using shrubs for cover sites. Tortoise burrows occurred almost exclusively at the bases of shrubs or in steep banks that actually bordered transition habitat where there was greater soil stabilization.

Rocky Habitat: Over one-half of the study site (57%) was covered by Rocky Habitat. Navajo sandstone formed rocky outcrops in which crevices and solution pockets formed numerous caves. These caves were utilized by tortoises as well as other vertebrates and invertebrates. The caves were sometimes extensive and were important wintering dens for the tortoises. Soils accumulated in cracks and depressions in the sandstone surfaces. These yielded high production of annual vegetation due to excess runoff from adjacent barren rock. Another feature of the sandstone outcrops are the expansive slabs that occurred without fissures in them. Consequently, large areas of this habitat type were devoid of vegetation.

Rocky Transition habitat: Numerous but relatively small patches of Rocky Transition habitat accounted for ~14% of the area. This habitat type is a broken land of poorly developed soil filling interstices in the numerous fissures in the sandstone substrate. The vegetation association was nearly solid Blackbrush (*Coleogyne ramosissima*). Presently, the role of this patch type in the ecology of tortoises is unknown. Tortoises may pass through this habitat only feeding opportunistically, especially in years of poor forage availability. The soils offered few opportunities for nesting or burrow excavation. Available cover sites tended to be large rocks or boulders, which afforded little cover or relief from temperature extremes.

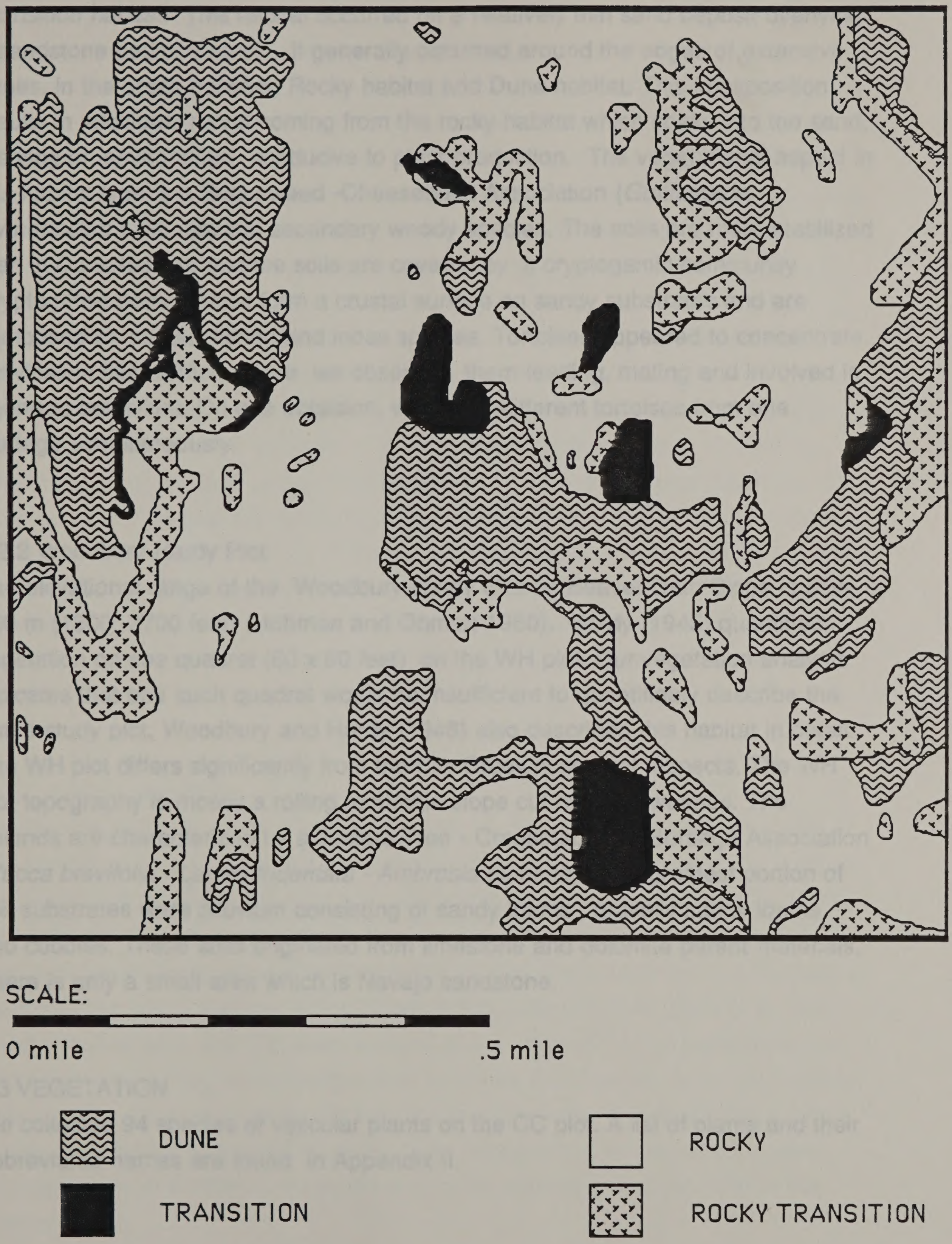


Fig. 9: Habitat Map of City Creek Plot; Washington Co., Utah. Esque, et. al., 1989 (adapted from Coffeen, et al., 1989).

Transition habitat: This habitat occurred on a relatively thin sand deposit overlying a sandstone bedrock apron. It generally occurred around the edges of extensive dunes, in the areas between Rocky habitat and Dune habitat. This juxtaposition results in additional runoff coming from the rocky habitat which soaks into the sand, creating an environment conducive to plant production. The vegetational aspect in this habitat type is a Snakeweed -Cheesebush Association (*Guttierrezia - Hymenoclea*) with several secondary woody species. The soils are more stabilized than in Dune habitat, and the soils are covered by a cryptogamic community . Cryptogamic communities form a crustal surface on sandy substrates and are composed of various lichen and moss species. Tortoises appeared to concentrate activities in this habitat, where we observed them feeding, mating and involved in agonistic behaviors. On one occasion, we saw 7 different tortoises from one vantage simultaneously.

4.2.2 Woodbury Hardy Plot

The elevational range of the Woodbury-Hardy Site on Beaver Dam Slope is 554-830 m (1800 -2700 feet) (Hohman and Ohmart 1980). Hardy (1945) quantified vegetation on one quadrat (60 x 60 feet) on the WH plot. Our vegetation analysis indicates that one such quadrat would be insufficient to quantifiably describe the entire study plot. Woodbury and Hardy (1948) also described this habitat in detail. The WH plot differs significantly from the City Creek in several respects. The WH plot topography is mostly a rolling mountain slope cut by deep washes. The uplands are characterized by a Joshua Tree - Creosotebush - Bursage Association (*Yucca brevifolia - Larrea tridentata - Ambrosia dumosa*) . The greatest portion of soil substrates were alluvium consisting of sandy loams , gravelly sandy loams, and cobbles. These soils originated from limestone and dolomite parent materials. There is only a small area which is Navajo sandstone.

4.3 VEGETATION

We collected 94 species of vascular plants on the CC plot. A list of plants and their abbreviated names are found in Appendix II.

4.3.1 Perennial Vegetation

Woody perennial vegetation (shrubs, trees) and cactus are known to provide tortoises with food (Kauffield 1943, Hohman and Ohmart 1980, Vaughan 1984) or fruiting bodies (Schneider 1980, Luckenbach 1982, Esque 1986) . The crowns and stems provide cover from intense sunlight in daylight hours and the roots stabilize loose soils, providing a medium for tortoise burrows (especially important in loose sandy soils). Also, this vegetation provides juvenile tortoises with cover which may reduce detection by predators (Berry and Turner 1986).

We collected 51 species of perennial plants. We completed 15 perennial belt transects, and 23 species of perennial plants occurred on these transects (Appendix III). Species compositions, mean cover, and mean densities for each habitat type are provided in Table 2. A similarity index was used to determine differentiation of species compositions between habitat patch types (Table 3). An index of zero indicated no similarity, and an index of one would indicate complete overlap of species composition. Although Transition and Dune appear to have the the most similar soil types, they are the least similar with regard for species composition of perennials. Rocky Transition and Transition have the most similar vegetational perennial components even though the substrates have different particle sizes.

4.3.2 Annual Vegetation

We identified 37 annual species on the entire study plot. We completed a total of 158 annual quadrats with about 40 quadrats in each of four habitat types. Table 4 represents the results of the annual vegetation quadrats by habitat type for 1989. The data represent a year in which the annuals suffered from early senescence due to high temperatures and low precipitation. For these reasons, the biomass of each species was probably underestimated due to an unknown amount of seed being dropped early and therefore was not being counted in our measurements. *Erodium* was probably underrepresented for cover. As *Erodium* cures, the leaves draw upward creating a growth form that covers less area than fresh green plants. However, *Erodium* is an early bloomer. If we changed our survey time to better estimate cover of *Erodium* , we would miss other species that grew later in the season.

Table 2: Perennial vegetation descriptive statistics: Mean density, mean frequency and % mean cover per habitat type at City Creek Study Site, in 1989. Code names are in Appendix II.

DUNE HABITAT (transects N = 4)

SPECIES	MEAN DENSITY	ST. DEV.	MEAN FREQUENCY	ST. DEV.	% MEAN COVER	ST. DEV.
ARFI	14.75	3.30	13.50	1.92	46.89	79190.68
CORA	0.75	1.50	0.50	1.00	0.81	5232.13
CRCA	2.25	2.06	1.75	1.50	0.47	1688.49
EPNE	35.75	11.90	11.25	2.75	41.25	70709.59
GUTT	4.25	8.50	3.00	6.00	2.41	15538.25
LORI	0.75	0.96	0.50	0.58	0.09	509.02
ORHY	2.25	1.71	1.25	0.96	0.16	353.53
PRFA	1.75	2.06	1.25	1.50	6.17	23076.29
STEPH	1.25	1.50	1.25	1.50	1.08	4621.31
YUUT	0.50	0.58	0.50	0.58	0.67	2780.00

TRANSITION HABITAT (transects N=5)

SPECIES	MEAN DENSITY	ST. DEV.	MEAN FREQUENCY	ST. DEV.	% MEAN COVER	ST. DEV.
ACAMP	0.40	0.89	0.40	0.89	0.05	286.68
BAMU	1.00	2.24	0.40	0.89	0.28	1695.30
CHRYSO	0.20	0.45	0.20	0.45	0.11	667.39
CORA	3.60	3.36	2.40	2.19	6.33	20820.42
ENFR	0.80	1.30	0.80	1.30	0.53	1960.40
EPNE	30.40	32.60	9.20	10.26	42.88	128134.72
ERFA	19.80	23.37	0.20	0.45	0.03	196.90
GUTT	46.00	28.50	16.20	6.61	28.43	59529.26
HYSA	2.20	3.03	2.00	2.74	1.31	5824.70
KRPA	5.80	5.93	5.00	5.10	10.56	28216.82
LATR	0.60	1.34	0.60	1.34	4.39	26684.37
ORHY	0.40	0.55	0.40	0.55	0.01	85.52
PRFA	0.80	0.84	0.80	0.84	4.76	21525.37
STEPH	0.40	0.55	0.40	0.55	0.31	1181.04
UNK	0.80	1.79	0.40	0.89	0.01	63.39

ROCKY TRANSITION HABITAT (transect N = 3)

SPECIES	MEAN DENSITY	ST. DEV.	MEAN FREQUENCY	ST. DEV.	% MEAN COVER	ST. DEV.
AMDU	0.67	1.16	0.33	0.58	0.03	157.96
ARFI	0.33	0.58	0.33	0.58	0.05	281.67
CORA	18.33	10.02	14.00	1.73	35.84	47301.90
CRCA	0.33	0.58	0.33	0.58	0.02	107.01
ENFR	1.67	2.89	1.33	2.31	1.51	7911.90
EPNE	24.00	21.93	12.33	5.13	28.26	56318.35
ERFA	0.67	1.16	0.67	1.16	0.91	4737.60
GUTT	29.00	5.29	10.00	0.00	12.63	13184.35
HYSA	3.33	5.77	2.33	4.04	3.51	18352.37
KRPA	2.33	3.22	1.67	2.08	4.39	16302.47
LATR	0.67	1.16	0.67	1.16	12.63	66080.02
OPER	0.33	0.58	0.33	0.58	0.00	0.59
PRFA	0.33	0.58	0.33	0.58	0.05	276.14
STEPH	0.67	1.16	0.67	1.16	0.17	878.02

ROCKY HABITAT (Transects N = 2)

SPECIES	MEAN DENSITY	ST. DEV.	MEAN FREQUENCY	ST. DEV.	% MEAN COVER	ST. DEV.
ARPU	1.00	1.41	3.50	4.95	3.06	5655.94
CORA	17.00	12.73	10.00	4.24	41.11	46733.54
ENFR	1.50	2.12	1.50	2.12	2.06	3814.75
EPNE	2.00	1.41	2.00	1.41	5.48	9918.79
ERFA	12.00	4.24	8.50	0.71	24.26	27607.99
GUTT	11.00	5.66	6.00	1.41	4.30	2150.73
HALA	4.00	4.24	3.50	3.54	1.33	2343.65
KRPA	2.00	1.41	2.00	1.41	5.03	3530.61
PRFA	3.00	4.24	1.50	2.12	12.84	23770.94
STEPH	1.00	1.41	1.00	1.41	0.53	989.20

Table 3: Similarity indices of perennial vegetation in each of four habitat types at City Creek Study Plot, St. George, Utah in 1989.

	Dune	Transition	Rocky Transition
Rocky	0.50	0.36	0.58
Rocky Transition	0.29	0.69	x
Transition	0.24	x	x

Table 4: Annual vegetation descriptive statistics: Mean density, mean cover, and mean biomass (per one sq. meter) per habitat type at City Creek Study Site, St. George, Utah, in 1989.

SPECIES	MEAN FREQUENCY	MEAN DENSITY	STAND. DEV.	MEAN COVER (sq. cm.)	STAND. DEV.	MEAN MASS (g)	STAND. DEV.
DUNE HABITAT (N=40)							
BRRU	0.48	4.50	8.80	5.88	14.04	0.06	0.15
BRTE	0.13	0.90	2.84	1.23	3.71	0.03	0.09
CRMI	0.23	4.05	19.44	7.06	35.00	0.02	0.10
ERCI	0.13	0.43	1.28	1.65	8.10	0.03	0.09
ERWA	0.05	0.15	0.80	0.13	0.56	0.00	0.01
EUPA	0.08	0.20	0.85	3.65	20.45	0.01	0.05
ERER	0.03	0.03	0.16	0.15	0.96	0.00	0.01
PLPU	0.03	0.05	0.32	0.03	0.16	0.00	0.00
SCBA	0.03	0.50	3.16	0.68	4.27	0.00	0.01
TRANSITION HABITAT (N=40)							
BRRU	0.88	27.13	35.42	37.76	56.79	0.76	1.35
BRTE	0.43	5.05	9.65	11.36	24.16	0.25	0.55
CRMI	0.08	7.35	32.45	0.79	4.43	0.01	0.06
ERCI	0.35	7.35	19.43	41.76	123.45	1.13	3.68
ERWA	0.38	2.53	5.13	2.04	3.99	0.02	0.05
ERER	0.13	0.18	0.50	0.73	3.37	0.00	0.01
PLPU	0.05	0.03	0.16	0.10	0.63	0.00	0.00
LINANTH.	0.03	0.28	1.74	0.35	2.21	0.01	0.04
MENTZ.	0.03	0.05	0.22	0.08	0.35	0.00	0.00
SCBA	0.05	0.10	0.50	0.13	0.56	0.00	0.00
ROCKY TRANSITION HABITAT (N=40)							
BRRU	0.90	33.28	38.54	41.83	66.34	0.55	0.68
BRTE	0.50	8.93	27.95	16.93	53.92	0.22	0.65
ERCI	0.05	0.05	0.22	0.38	1.94	0.00	0.02
ROCKY HABITAT (N=38)							
BRRU	0.58	27.47	42.38	32.37	51.36	0.42	0.66
BRTE	0.29	4.13	10.93	6.72	17.28	0.09	0.23
SCBA	0.03	0.03	0.16	0.03	0.16	0.00	0.00

Voucher specimens were collected and prepared for a field file. We located 11 species of annual plants on the vegetation quadrats. The most abundant species of annuals were three exotics: Red Brome (*Bromus rubens)*, *Bromus tectorum* and Filaree (*Erodium cicutarium)*. Annual species diversity was greatest in Transition habitat (10 species) and Dune habitat (11 species). Rocky transition and Rocky habitats had considerably less diversity (each with three species) . Using a similarity index (Table 5), the annual plant compositions of Transition and Dune habitat were most similar. Transition habitat was most dissimilar with either Rocky or Rocky Transition habitats.

Table 5: Similarity indices of annual vegetation in each of four habitat types at City Creek Study Plot, St. George, Utah in 1989.

	Dune	Transition	Rocky Transition
Rocky	0.25	0.23	0.33
Rocky Transition	0.25	0.23	x
Transition	0.42	x	x

The 1989 field season was arid, being one of the lowest annual accumulations of rainfall during the past 20 years. The effects of these conditions produced a short growing season and desiccation of plant species. Brief rains during May 1989 resulted in a revival of *Erodium cicutarium* plants that were not completely desiccated already. Just prior to the rains, the *Erodium* plants were becoming very dry; however, these rains caused the *Erodium* to "green up" and resume acquiring more vegetative biomass and restore flowering for a short time. Mean diameter of *Erodium* vegetative portions was 4.3 cm based on herbarium specimens (N=6) of representative plants from the plot. Highly productive patches on the plot were at the "Indian Dune" (near stake #57) and "Twist Hollow Wash", along the northwestern corner of the plot. At the "Indian Dune," unusually large *Erodium* plants were found. Many of the plant specimens were five times the diameter of those plants found elsewhere on the study plot. In the "Twist Hollow Wash," *Bromus spp.* formed a monoculture along the wash in deep, fine-grained,

loamy sands. In 1989 the density, diversity and biomass of some species such as Woolly Daisy (*Eriophyllum wallacei*) and Dye Cryptanth (*Cryptantha micrantha*) were considerably lower than were observed in 1988 (T. Esque, unpubl. field notes and photographs 1988) at the CC plot.

General survey of Woodbury-Hardy (Utah) and Littlefield (Arizona) plots indicated low biomass production of winter annuals in those locations in 1989. The 1989 field season was generally a drought year in the Mojave Desert, for example, researchers in Rock Valley, northwest of Las Vegas,Nevada, found no winter annual production in 1989 (Medica 1990).

4. 4 FIELD DATA ON DESERT TORTOISES

4.4.1 Observation Techniques

Tortoises were radio-fitted on 16 - 30 April 1989 (Table 6). Nine of 10 radio-transmitters at the CC plot persisted from 16 April through 14 October 1989. One transmitter ceased operating about one month into the study. That tortoise has been re-located in her winter den and will be re-radioed in spring 1990. The same group of animals will be observed through the 1990 field season.

Table 6: Attributes of radio-telemetered tortoises at the City Creek Plot, St. George, Utah, in 1989. All female tortoises.

Tortoise Channel	Date Found	Maximum Carapace Length (MCL)	Mass (kg)
1.42	APRIL 24 1989	246	2.40
2.42	APRIL 16 1989	--	2.60
4.15	APRIL 28 1989	228	2.20
4.41	APRIL 24 1989	251	3.26
7.08	APRIL 22 1989	203	1.68
7.40	APRIL 27 1989	247	2.58
8.21	APRIL 28 1989	232	2.65
10.21	APRIL 30 1989	240	2.45
11.00	APRIL 24 1989	226	2.15
11.38	APRIL 25 1989	223	2.15

By the time the tortoises were radio-fitted, they had switched into a bi-modal activity regime. Several of the radio-tortoises were seen foraging the day following their radio-attachment. Only one tortoise may have been disturbed. It retreated into a deep rock cave for two days after the attachment of the transmitter. However, some tortoises are not active every day (Nagy and Medica, 1986).

Tortoises could be observed between 5 and 15 m (depending on the individual tortoise) without response by the tortoise. We began observation periods with great caution to avoid disturbing tortoises. We learned early that talking in low voices or, more often, moving too quickly disturbed tortoise behavior. In the event that an observer approached too rapidly or too closely, the tortoises responded in one of two ways. If they were some distance from burrows, they responded by stopping and lowering their bodies until they were flush with the ground. Such movements were smooth and gradual, attracting a minimum of attention. Usually they lowered their posterior ends first and this movement was so smooth that it resembled the lowering of a hydraulic lift. Also, if tortoises were within a few meters of their burrows, they responded to disturbance by hurrying toward or into their cover sites. On four occasions, a large male tortoise, living at a cave with a good view of the surrounding area, was observed at a distance of >150 meters. As several other observers came over the horizon and into plain view, the tortoise scurried a distance of 2 meters into a cave with great haste. At the onset of any disturbed behavior, we retreated slowly and monitored the animal at a greater distance. It usually took 20 minutes or less for the tortoise to resume normal behavior unless they were disturbed near a burrow, in which case they often did not re-emerge for the rest of that morning. After two or three observation periods, most of the animals were approachable to within at least 15 meters. However, some individuals remained wary and required care in stalking. Conversely, one tortoise being recorded on videotape walked into the shade of the photographer and proceeded across the person's boot, eating food all the while.

4.4.2 Activity Periods

Our records of spring activity were between about 14 April and 20 June, 1989. We believe that this time span encompassed the peak activity for the tortoises; however, it was obvious that some animals had been active already this year. Prior to and just after that time period, a substantial decrease in the number of tortoise

tracks corroborated the results of our radio-tracking efforts. During a brief period of thunder showers on May 16, tortoise activity increased.

4.4.3 Bite-Count Results

The major period for observations of tortoises foraging was between 14 April and 20 June 1989, and two field personnel observed tortoises almost every day. After 20 June, only one field person was employed, and that individual did not work at City Creek full time. We collected bite-count data on nine of ten radio telemetered tortoises. Analyses for two time periods of bite-count studies are in Table 7.

Table 7: Comparison of tortoise observation and bite count data for two time periods at the City Creek Plot in St. George, Utah in 1989.

	14 April to 20 June	14 April to end of August
Hours of Observation	240.0	332.0
Number of Observations	165.0	285.0
Total Foraging Time (hours)	37.3	39.0
Number of Foraging Observations	46.0	57.0
Number of Bites	11152.0	11703.0
Mean Foraging Time/ Foraging Bout	47±49	43±47
Mean Number of Bites/Foraging Bout	242.0 ± 250	213.8 ± 239.2

4.4.4 Feeding Rates

The mean feeding rate for tortoises was 3.88g/hr for a tortoise weighing 2.41 kg (Appendix IV). This is considered to be a maximum foraging rate because, in the calculation of that figure, we considered tortoises to have eaten every day, which is probably not the case. *Bromus spp.* composed ~50 % of the bites counted at City Creek in 1989. The dry mass of a bite of *B. rubens* seed head was estimated to be 0.019 g (n=20, SD = .01). Tortoises were observed to have consumed a *Bromus rubens* seed head in two bites, therefore, a single bite weighed 0.0095 g (dry mass). Using these calculations, a hypothetical tortoise weighing 2.41 kg (mean mass for our 10 radio telemetered tortoises) consumed 184.14 grams of dry forage in spring of 1989. These feeding rates may be highly variable. Since estimates

were calculated for only one plant species in 1989, they are crude estimates which should be used conservatively.

4.4.5 Diet

Twenty-nine food items were consumed during bite-count observations (Table 8, 9). Of those items, 13 were annual plants or biennial plants,12 were perennials, and 4 were not plant materials. Of the perennial species consumed, Range Ratany (*Krameria)* was the only woody shrub with greater than 1% use at City Creek. In late April, we observed tortoises foraging on *Krameria* flowers and leaves. Later in May, adult tortoises foraged on ripening seed pods. On many occasions, tortoises were seen with deep purple smears on their beaks indicating that they had been eating *Krameria*, which was the only common plant with purple flowers at that time. Once a tortoise was seen climbing onto *Krameria* shrubs so that its fore-quarters were off the ground allowing it access to *Krameria* seed pods. Two perennial grasses each composed greater than 1% of the bites counted. The grasses were Indian Ricegrass (*Oryzopsis hymenoides*) and Big Galletta Grass (*Hilaria rigida*).

We observed tortoises at the WH plot on four occasions, but statistical analyses were not possible on these few observations. Tortoises on the WH plot ate *Bromus rubens, B. tectorum, Erioneuron pilosum*, and *Aristida purpurea. Erioneuron* is also known to be eaten at sites in Nevada (Esque and Duncan 1985).

4.4.6 OSTEOPHAGY, LITHOPHAGY, AND GEOPHAGY

Besides plant materials, tortoises were observed consuming bone (osteophagy), rock (lithophagy), scat (coprophagy), and soil (lithophagy) (Table 9). We observed tortoises eating bone at the CC plot as well as the WH plot on the Beaver Dam Slope. At the CC plot, we saw tortoises consuming weathered bones of cattle. On one occasion, we filmed this activity with a video camera.The surfaces of the bones flaked off and the inner layers were crumbly, so that the bones could be crushed into powder between our fingers. Since tortoises do not have teeth, they do not gnaw bones and leave grooves in the material like rodents. We did, however, observe and photograph locations where tortoise tracks accumulated around old bones, possibly indicating foraging activity. Tortoises on the Beaver Dam Slope also were observed eating rabbit bones. During both instances of osteophagy, the tortoises were persistent

Table 8: List of plant species consumed by tortoises at City Creek, Utah: 14 April to 20 June 1989. Code names found in Appendix II.

SPECIES	# BITES TOTAL	** % BITES
BRRU	6245	52.15
ERCI	2687	22.44
BRTE	945	7.89
KRPA	488	4.08
HIRI	327	2.73
CRMI	182	1.52
ORHY	143	1.19
EUPA	119	0.99
OEPA	92	0.77
HEAN	86	0.72
OPER	57	0.48
STPA	53	0.44
ARPU	46	0.38
UNK	44	0.37
EPNE	33	0.28
LASC	33	0.28
TRMU	33	0.28
ERWA	12	0.10
CORA	7	0.06
GUTT	6	0.05
HYFI	5	0.04
HEVI	2	0.02
CRNE	1	0.01
*ENFR	0	0.00
TOTAL	11654	97.34

*trace amount

** The percent of bites includes the consumption of both vegetative and non-vegetative food items.

Note: Genus and species names may be found in Appendix II.

Table 9: Comparison of percent occurrence of food items and other items in bite-counts versus scats at City Creek Study Plot, St. George, Utah, in 1989. Scats are reported as percent occurrence in samples analyzed.

SPECIES	# BITES TOTAL	%BITES	% SCATS
BRRU	6245	52.15	93.75
ERCI	2687	22.44	89.58
BRTE	945	7.89	0.00
KRPA	488	4.08	30.38
HIRI	327	2.73	14.58
CRMI	182	1.52	4.17
ERPU	171	1.43	2.08
ORHY	143	1.19	14.58
EUPA	119	0.99	0.00
ARPU	46	0.38	18.75
CACTUS	57	0.48	20.83
OEPA	92	0.77	8.33
CORA	8	0.07	10.42
EPNE	33	0.28	20.83
MOSS	0	0.00	25.00
BONE	55	0.46	*NA
ROCK	51	0.43	NA
SOIL	25	0.21	NA
SCAT	18	0.15	NA
ARTH	0	0.00	NA

* These items are not comparable using microhistological techniques

in attempts to acquire bone material. In both cases, we became so enthused with observing the activity and accurately recording the substance which was being eaten, that we approached more closely than usual. In both cases, the tortoises paused briefly when disturbed, but continued their pursuit of consuming bone material (contrary to general feeding behaviors).

Tortoises were observed ingesting white rocks of small size on several occasions at the CC site. We speculate either that the rocks were mistaken for bone or that the tortoises ingested such stones for the purpose of assimilating calcium or other minerals in the rock. We did not observe soil-eating or mining by tortoises which was reported by Marlow and Tollestrop (1982). We did, however, collect fecal specimens composed primarily of sandy soil.

4.5 FECAL ANALYSIS

We had 59 fecal samples (scats) analyzed for plant species content. These scats contained 28 species of plants (Appendix V). Our early sample (2 May - 31 May) had 18 species of plants present. Our late sample of scats had 21 species of plants. The greater number of species in the second sample could be the result of slow passage rates of tortoises. For example, scat data for the late sample could have carried over species from plants only present in the early season. But scats collected later within the second period would be expected to have later blooming species present. One way to solve this problem of interpretations would be to collect a greater number of scats over a greater time span, and leave two-week intervals between sample periods.

In comparison, bite-count techniques resulted in a list of 24 species of plants. There were differences in the abundance and diversity of the plant species which occurred in scat analyses versus bite counts (Table 9). More perennial than annual species were present in both early and late scat analyses. In contrast, the number of perennials was close to the number of annuals present in the bite-count analysis. Three species that occurred in the bite-counts were not present in the scat analysis. Scat analysis provided 12 plant species which were not observed during bite counts.

4.6 NUTRITIONAL ANALYSIS OF DIET

Lists of plant species collected for nutritional analysis at tortoise study plots in 1989 are in Appendix VI. The role of the plants which tortoises ate cannot be determined without the laboratory analysis of those plants collected. Results of the laboratory analysis were not available for this report (Flinders et al. - in prep).

4.7 HOME RANGE AND PATCH USE

Home range sizes for tortoises are provided in Table 10. The mean home range for a tortoise at City Creek was 20.51 hectares considering all location points as one set of data (n=9, s.d.=11.086). One tortoise (#2.42) was not included in the analysis since its radio failed early in the study. While most of the tortoises remained in a localized home range, two tortoises spent time in one location and then travelled to another part of the study plot or commuted back and forth between sites. When home range was calculated considering these movements(using two subsets within a single home range), the mean home range for all tortoise was

slightly smaller (18.8 hectares, range=7.3-30.2 ha, n=9, s.d.=11.4). The spatial pattern of home ranges for individual desert tortoises differs in size and shape (Fig. 10).

Tortoises were observed in all four habitat types (Dune, Transition, Rocky Transition, and Rocky habitats); however, more time was spent by tortoises in Dune and Rocky habitats than the other two habitats . Time spent in Rocky habitat was accumulated at the beginning and ends of the spring activity period, as deep caves within Rocky habitat were used by all tortoises for estivation. Tortoises spent the most time feeding in Transition habitat (Figure 9). There was a strong negative correlation between amount of habitat type present versus the amount of time spent feeding (Fig. 10).

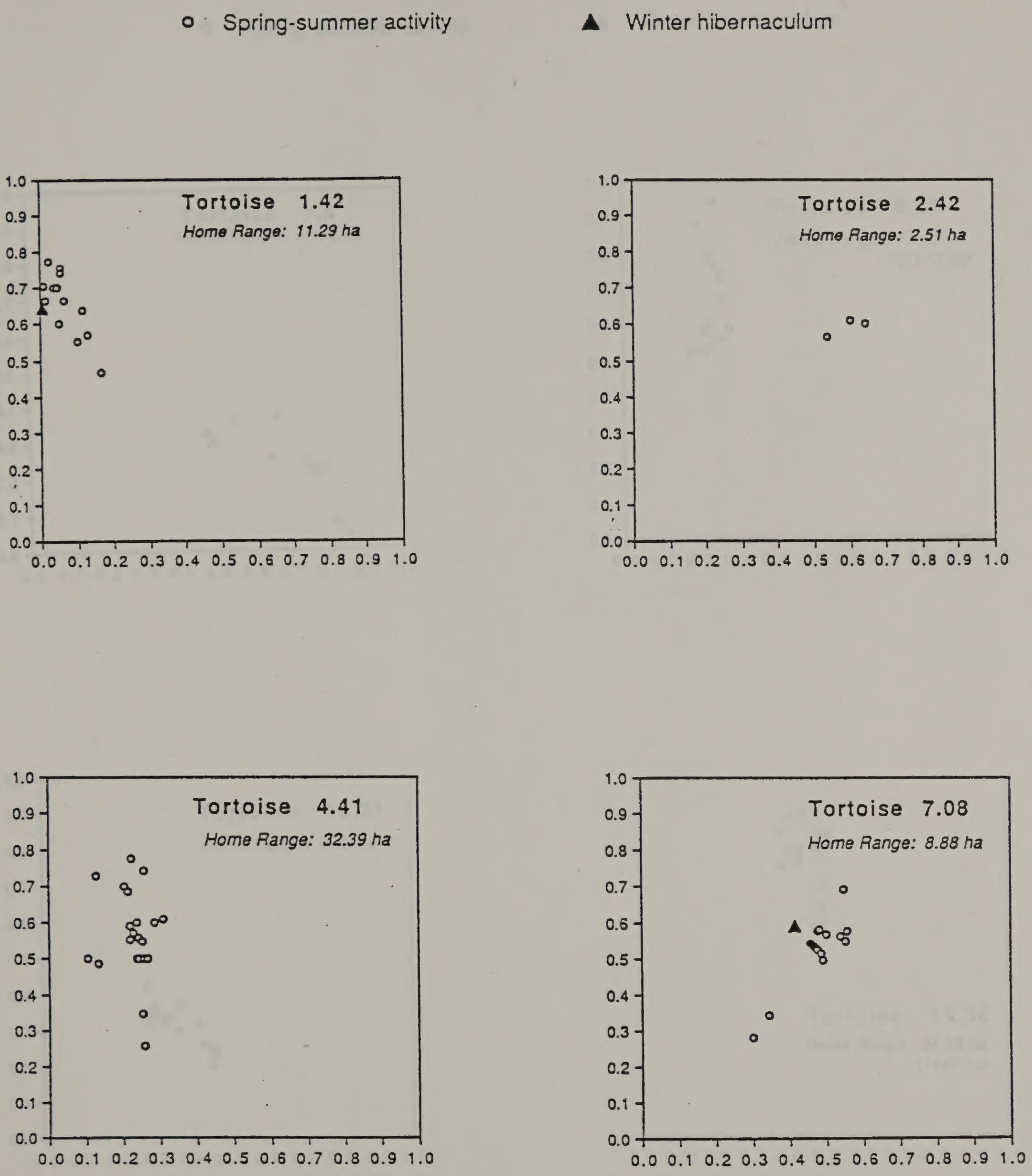
Table 10: Home range sizes for desert tortoises at City Creek Study Plot. 14 April through 20 June, 1989.

TORTOISE CHANNEL	ENTIRE RANGE (Ha)	*SPLIT RANGE (Ha)
1.42	11.29	
2.42	2.51	
4.15	16.55	17.47
4.41	32.39	
7.08	8.88	
7.40	41.76	
8.21	17.83	11.13
10.21	9.19	
11.00	22.12	
11.38	24.59	14.67

* calculated for tortoises with two distinct activity areas.

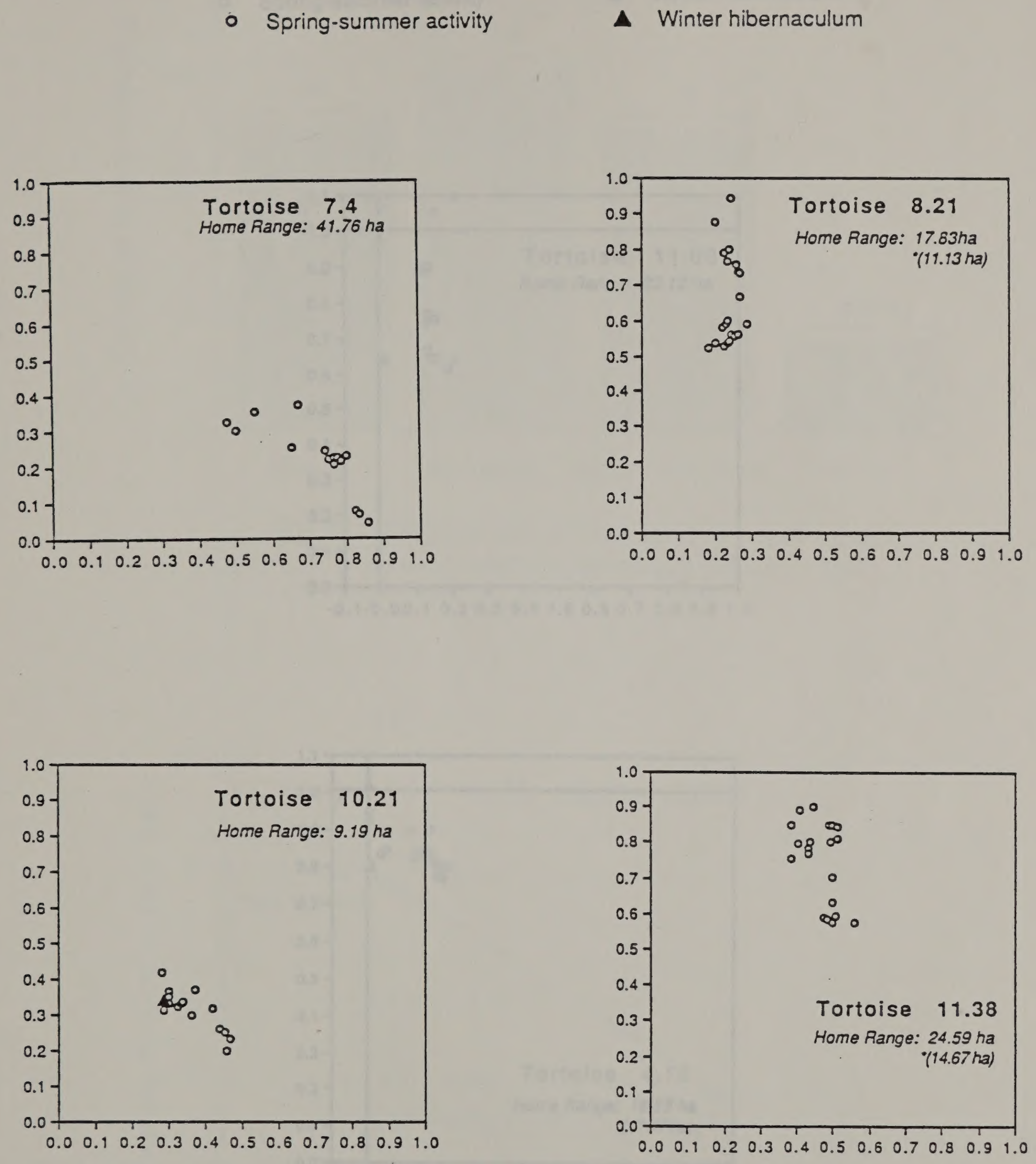
This relationship suggests that there is some aspect of the Transition habitat that is very attractive to the tortoises. Analysis of herbaceous plant production data illustrates a poor correlation between production and time spent feeding; therefore, biomass production alone does not account for this usage pattern (Fig. 11) . Subsequent data collection will be necessary to assess factors contributing to this behavior pattern.

Figure 10 (a-d). City Creek Desert Tortoise Home Ranges, 1989.*



*Note - each map increment is equal to 1/10 of a mile.

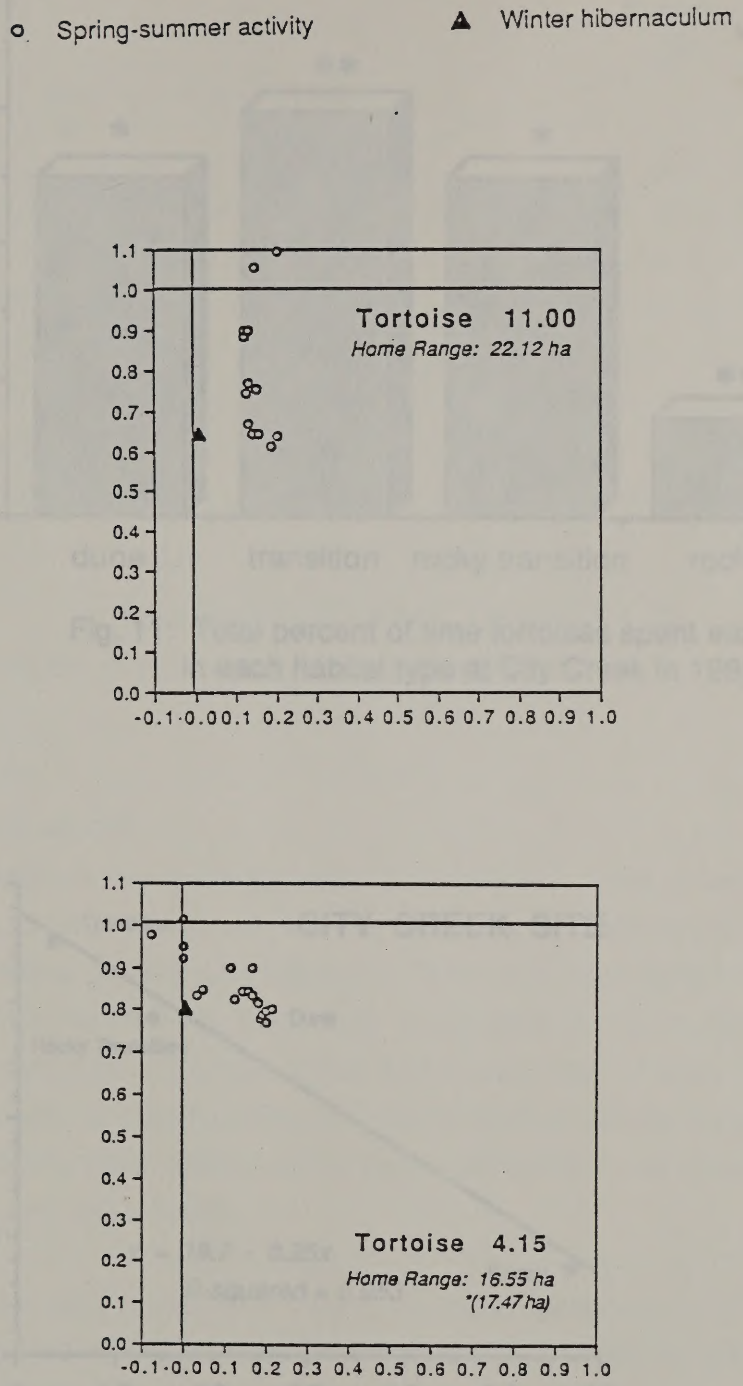
Figure 10 (e-h). City Creek Desert Tortoise Home Ranges, 1989.*



*Parenthetical value refers to split home range (see text).

*Note - each map increment is equal to 1/10 of a mile.

Figure 10 (i-j). City Creek Desert Tortoise Home Ranges, 1989.*



•Parenthetical value refers to split home range (see text).

*Note - each map increment is equal to 1/10 of a mile.

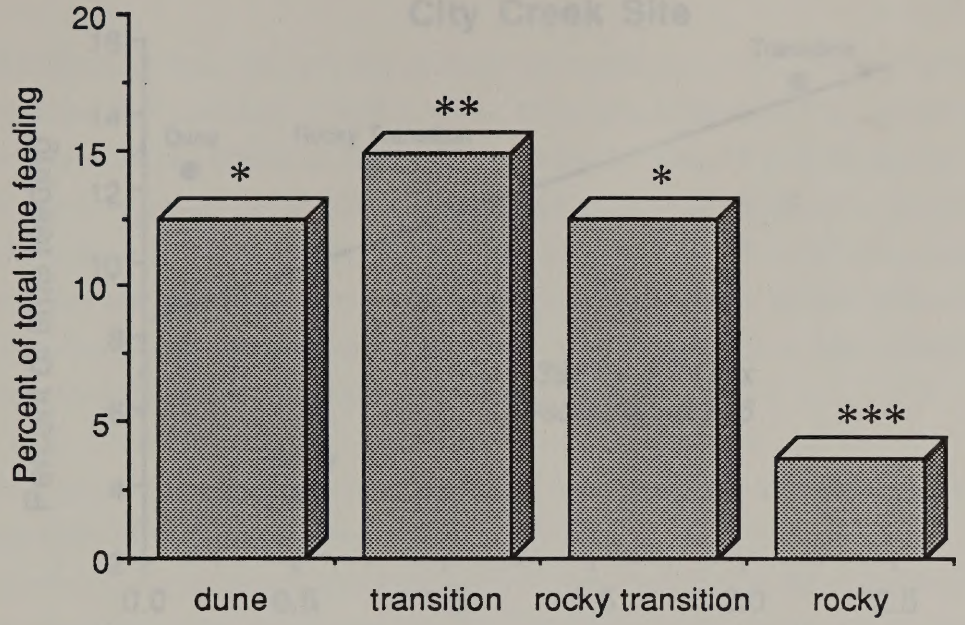


Fig. 11: Total percent of time tortoises spent eating in each habitat type at City Creek in 1989.

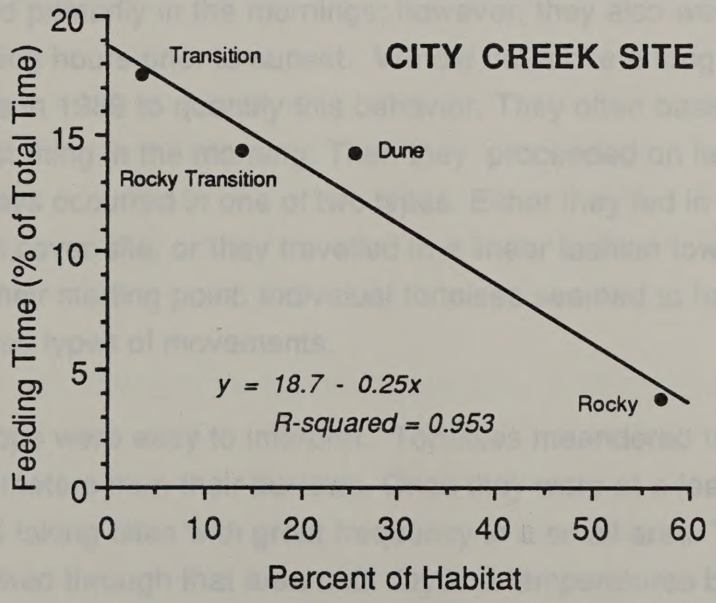


Fig. 12: Correlation of feeding time and percent of habitat.

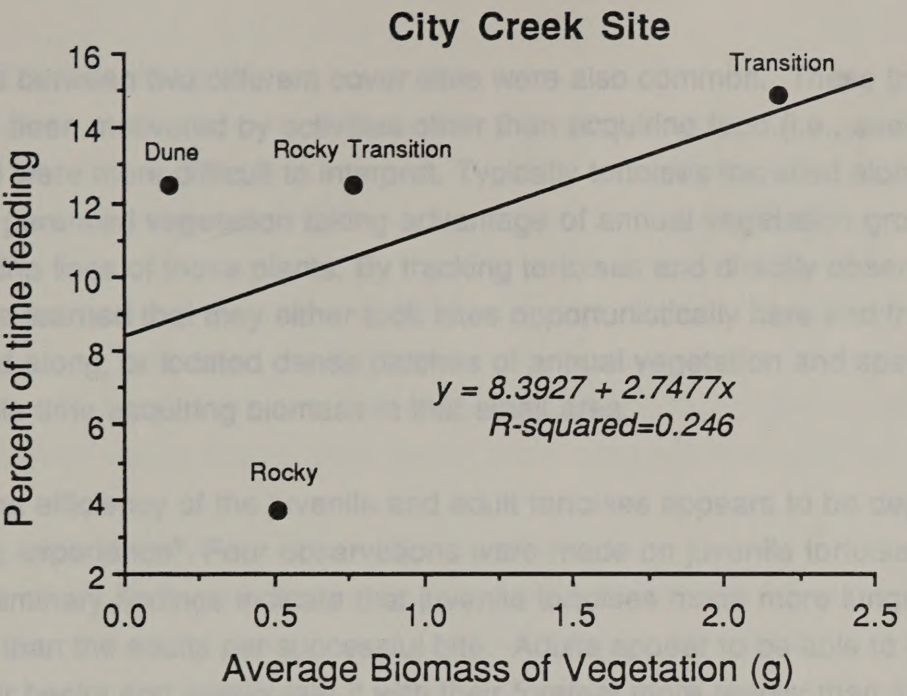


Fig. 13: Percent of time spent feeding and total biomass of vegetation available.

4.8 FORAGING BEHAVIOR

Tortoises fed primarily in the mornings; however, they also were observed feeding during evening hours prior to sunset. We did not make enough evening observations in 1989 to quantify this behavior. They often basked at their burrow entrance first thing in the morning. Then they proceeded on feeding forays. Feeding forays occurred in one of two types. Either they fed in a loop, returning to their original cover site, or they travelled in a linear fashion toward a cover site other than their starting point. Individual tortoises seemed to have preferences for either of these types of movements.

Foraging loops were easy to interpret. Tortoises meandered toward a feeding area perhaps 20 meters from their burrows. Once they were at a feeding area, they commenced taking bites with great frequency in a small area. These tortoises typically walked through that area until daytime temperatures became too high. At the conclusion of a feeding bout, they retreated in a directed manner toward their original burrow. During their retreat toward burrows, the tortoises usually travelled at a noticeably quicker rate.

Movements between two different cover sites were also common. These travels could have been motivated by activities other than acquiring food (i.e., seeking mates) and were more difficult to interpret. Typically tortoises travelled along patches of perennial vegetation taking advantage of annual vegetation growing within the drip lines of those plants. By tracking tortoises and directly observing tortoises we learned that they either took bites opportunistically here and there as they walked along, or located dense patches of annual vegetation and spent considerable time acquiring biomass in that small area.

The foraging efficiency of the juvenile and adult tortoises appears to be dependent on "feeding experience". Four observations were made on juvenile tortoises in 1989. Preliminary findings indicate that juvenile tortoises made more lunges at food items than the adults per successful bite. Adults appear to be able to grasp food in their beaks and manipulate it with their forefeet more readily than juveniles.

4.9 AGONISTIC BEHAVIOR

We observed female - female agonistic behaviors on 3 occasions. One of each pair was one of our radioed tortoises. In each case a larger body-size tortoise was the aggressor. One of these encounters occurred early in the spring at a wintering den and on two occasions the encounters took place in separate Transition habitat patches where tortoises are known to feed and mate. In one instance, female - male agonistic behavior was observed at the City Creek Plot. In this case, an adult female was the aggressor in an encounter with a subadult male at a wintering cave. Agonistic behaviors were not observed at the WH site. This was probably because of limited time spent at that site.

On June 23, gila monster (*Heloderma suspectum cinctum*) tracks were seen at the entrance of a tortoise burrow. Radio-tortoise #7.08 was at the entrance and she quickly emerged from her burrow and blocked the entrance by wedging herself sideways in the burrow. On July 13, we found egg shells at that location. Even after the eggshell appeared, this tortoise continued to guard her burrow by charging out from inside the burrow to either face us or to block the entrance. Barrett and Humphrey (1986) described a similar encounter with a gila monster in Arizona. Kit fox tracks and signs of excavation (digging and collapsing of burrow entrance) suggest that the fox may have tried to get to the tortoise eggs as well.

4.10 TORTOISE HEALTH

We observed no sign of the Upper Respiratory Disease Syndrome at the CC plot in 1989. Soft bodied ticks, which are usually found on desert tortoises in other parts of their range, were not observed on any tortoise at the City Creek plot.

We did observe one radioed-tortoise with a runny nose and watery eyes at the WH plot. That tortoise is involved in a long-term study on reproduction of the desert tortoise, and will continue to be monitored by the UDWR (M. Coffeen – pers. comm.) Tortoises on the Beaver Dam Slope, Utah, carry soft bodied ticks.

4.11 METHODS FOR SAMPLING TORTOISE DIET

Prior to developing a technique for sampling stomach contents, it was necessary to investigate gastrointestinal morphology, and the condition of gastrointestinal contents. Stomach samples were drawn from a preserved specimen of a male tortoise reported to have been collected on the Beaver Dam Slope, Utah, and one specimen reportedly retrieved from Paradise Canyon, 3 mi. north of St. George, Utah. Samples were collected from the anterior 1/3 of the duodenum, the posterior 1/3 of the duodenum and the rectum of the Beaver Dam Slope animal. We found hundreds of small (3-5 mm length) parasitic worms in the anterior 1/3 of the duodenum. The contents were of much smaller particle size than would have been expected judging by the particle sizes found in most scats, which suggests putrification of the gut contents We also collected stomach contents from the stomach and duodenum of the Paradise Canyon specimen. In general, the stomach contents were extremely coarse and had been formed into a loose food bolus due to the long fibers in the food.

For one gastrointestinal tract preserved in 70% ethyl alcohol, we measured the entire digestive system (Beaver Dam Slope specimen #239). The total length of the gastrointestinal tract was 90.7 cm: the esophagus reached 9.1 cm; the stomach, 11.3 cm (including pylorus); small intestine, 30.8 cm; the partial cecum, 6.3 cm; large intestine, 27.2 cm; and the length of the rectum was 6.0 cm.

4.11.1 CAPTIVE TORTOISES

After investigating gut morphology of preserved specimens, we used captive animals to develop techniques. Six tortoises arrived in a communal cage from Las Vegas, Nevada. One tortoise (#6) had signs of disease upon arrival: a viscous,

translucent discharge of myxoid substance came from the nostrils. That tortoise had a low white blood cell count. This tortoise was also lethargic. Laboratory results of nasal smear indicated the presence of the bacterium *Pasteurella testudinis*. Chloramphenical was prescribed and administered intramuscularly for 10 successive days. Additionally, medicated nasal drops were administered. The tortoise increased eating after treatment, and the signs of disease had cleared up entirely after a month. Subsequently, the animal has had such signs intermittently. This indicates that this illness may be the chronic condition known as the Upper Respiratory Disease Syndrome which is prevalent in many captives and in some wild populations.

4.11.2 SAMPLING STOMACH CONTENTS

We attempted to use a gavage tube and syringe to extract a small sample of stomach contents from live tortoises. Various methods of gavage were attempted. A commercial rubber tube was used as well as commercial stainless steel tubes to accommodate a bend in the gastrointestinal tract just at the entrance into the stomach. All animals were sedated during these trials with ketamine chloride . The anaesthetic was administered by Howard Martin, D.V.M., CSU Veterinary Teaching Hospital. Ketamine is a safe and commonly used sedative for reptiles. There were no mortalities using the drug. Dosages were 10 ml/ kg of tortoise biomass. For exceptionally large tortoises, 11 or 15 ml/ kg were used. Under the effect of the ketamine, tortoises were conscious and they did not require respirators, yet were docile and easy to manipulate. Tortoises retained some mobility, but by elevating a tortoise with a small pedestal (slightly smaller than the diameter of the plastron) their feet did not offer resistance when tortoises moved their legs.

Our first method entailed filling a syringe with saline solution and introducing a small amount of it into the stomach. We intended to then extract a stomach sample by drawing the fluids back into the syringe. This did not result in adequate sample size, and flushing out the stomach was not feasible during this techniques trial.

Examination of dissected tortoise specimens (salvaged) indicated that the foods of tortoises are often fibrous and undigested in the stomach and form a loose bolus that is of greater diameter than the anterior sphincter. For that reason, using various chemicals to induce the animal to regurgitate the food were out of the question.

4.11.3 FIBEROPTICS

A plastic syringe canister was cut off on one end and filed down for use as a bit on the tortoises. This device was narrow enough to minimize any jaw discomfort; in addition, it created a sufficient portal through which the delicate fiberscope could be introduced without any risk of damage due to the tortoises bite.

At first, we used a bronchoscope (5 mm diameter) to view the food in the tortoise's stomach. The procedure was facilitated with air and water added through the scope portal, which helped to open up the passage and make viewing clearer. Any air that was added during the procedure was pulled out of the tract as the scope was withdrawn. The water that was added was minimal and didn't pose any danger to the tortoise' s system. Through the scope ocular we were able to view the contents of the stomach. Using alligator grabbers, we attempted to extract stomach contents for identification. The grabbers retrieved small portions of the food residing in the stomach.

We obtained a flexible ureterscope from Surgitek through Alfred Defalco, M.D., an experienced endoscopist. Also, he offered new insight and assistance into the problem of non-destructive sampling of stomach contents. Using a three millimeter diameter scope, we were able to view the gastrointestinal tract. But for sampling the stomach contents, we found that a standard cystoscope suited our purposes better. This device has a long metal extension (approximately 20 cm) that was passed through a relaxed tortoise's throat passage. Through the cystoscope's simplified structure, we were able to view the stomach contents with greater clarity than with the flexible fiberscope. In addition, the scope may be used in tandem with specially refined retrieval tools. We used a three-point grabber and a three-point basket to retrieve the contents of the stomach. These tools are normally used in humans to retrieve bladder or kidney stones. Tortoises which we examined were fed dandelion greens and flowers about 4 hours earlier. We found that the food parts were backed up against the posterior of the stomach and had the consistency of steamed spinach.

The rigid cystoscope and the flexible fiberscope may be used in tandem to remove stomach contents of desert tortoises. Once the tortoise has been relaxed, the cystoscope allows efficient removal of stomach contents in 5 to 10 minutes. We feel

that this technique would yield results that are consistent with those of the other two techniques, including efficiency (monetary investment), potential for large sample size, repeatability, and reliability. We are developing a modified biopsy tool designed to gather food samples more efficiently.

5.0 DISCUSSION

5.1 VEGETATION ANALYSIS

The degree of variation within our vegetation transects was high. On future transects, the use of line–intercept techniques will probably provide better perennial data results than multiple belt transects because they are more time efficient. Also, we will be able to complete more transects resulting in a greater sample size and precision.

Further, our random plots will be difficult to replicate in successive years. For that reason, we suggest associating the annual vegetation quadrats with the line-intercept transects. Both changes in technique will be suited for assessing trends at permanent trend plots.

We found that the analysis of the data collected on annual vegetation transects need refinement. It was inefficient to survey annuals at random across the entire plot. The results had great variation, which may be eliminated or reduced by fine-tuning habitat descriptions and adding habitat types (greater stratification). But desert habitats are inherently patchy, which caused large standard deviations in our results.

In the past, most studies of vegetation at desert tortoise study plots did not include any analysis of variation. This may result in misleading interpretations because these data are used to estimate how much food is available for various herbivores. For example, simply stating that there is a mean biomass of 25 grams dry mass per square meter might give the impression that the desert was fairly lush. However, environmental conditions can create a great deal of patchiness in distribution of biomass. If variation is not taken into account when analyzing production figures, patchiness causes an overestimation of biomass over a large area.

5.2 TORTOISE DIET

In 1989 tortoises consumed >85% exotic annuals. The high incidence of eating exotics this year was probably due to the fact that those plants were the most abundant food plants available during a drought year. In general, the species consumed during bite-counts did not vary greatly from data generated by scat analysis. The scat analysis yielded a longer list of species, but this technique is not

useful for quantifying biomass consumption. Clearly, further analysis of this relationship is required. At this time we suggest that both techniques be continued for another year.

Observations of tortoises biting and ingesting bone and rocks were striking, and tortoises were persistent in acquiring those materials. Our observations suggest that such behavior is important to tortoises not due to novelty, but because it is a repeatedly observed phenomenon in both captive and wild tortoises (Bally 1946, Sokol 1971, Marlow and Tollestrup 1982, Marlow 1979,). Although often noted in literature and reports, the importance of this behavior in maintaining the health of the animals is poorly understood for tortoises.

Owners of captive tortoises note that their pets will consume white rocks or egg shells (J. Hohman, pers. com.). Captive tortoises are regularly fed bone meal (B. Burge, pers. comm.). X-rays of adult tortoises at the Nevada test site show most tortoises with small rocks in the intestine (R. B. Bury observation). Sokol (1971) discussed lithophagia and geophagia in desert tortoises and speculated that in contrast to insectivorous reptiles (which may utilize rocks in the gut for commination of chitinous materials), tortoises probably consume calcareous rocks to supplement diet calcium. Marlow and Tollestrup (1976) documented the use of mineral mines by desert tortoises. Several other field researchers have noted the incidence of geophagia (Hallinan 1923, Bisset 1972, Murphy 1973, Luckenbach 1982, Turner and Berry 1984, Obst 1986).

If calcium and bone minerals are vital resources for tortoises at some stage in their life history, we suggest that availability of such nutrients could effect the distribution and survival of desert tortoises. Similarly, the distribution of the Bolson tortoise (*Gopherus flavomarginatus*) has been correlated with the occurrence of calcium deposits in soils (Morafka et al. 1989). This suggests that the available forage may not supply adequate dietary levels or that additional supplementation is needed. If tortoises require supplemental minerals and acquire them by eating bones, we speculate that tortoise bones from carcasses would be of value to live tortoises. If mineral supply is limiting, we question the prudence of collecting tortoise skeletons from study plots (currently a routine procedure), since this practice may ultimately deplete necessary tortoise mineral reserves from the ecosystem. In fact, "aged" tortoise bones now tend to be rare on BLM Permanent Study Plots because all

tortoise carcasses are collected as population surveys are initiated. After an initial BLM and state surveys, shell remains seldom have the opportunity to accumulate or deteriorate to the advanced stages because they are collected at intervals as part of standard survey procedure. After being collected, these carcasses are stored at repositories.

As an alternative to collecting all tortoise mortalities, we suggest collecting a subset of the total number of shells present. We point out that biologists should consider alternatives for future research so as to minimize impact on the creatures we seek to conserve and to study.

5.3 HOME RANGES

The home range size estimates calculated for the 1989 field season were small (mean = 20.5 ha; N=9 tortoises), and may have been affected by the abnormally dry conditions. Burge and Bradley (1976) and Sheppard (1982) indicate that tortoises have greater home range sizes in years of high primary production, but the effect of poor forage availability on tortoise activity is not quantified at City Creek or other areas. Further records are needed in 1990 and beyond for an estimate of the tortoises' home range under varying environmental conditions.

Tortoises may reside in loose colonies (Woodbury and Hardy 1948). However, social structure (e.g., dominance) and territorially remain speculative topics. We recommend checking tortoises carefully to identify the sex and size classes of individuals because generalizations of behavior may lead casual observers to interpret most agonistic encounters to be between males (when sometimes females are involved). Accurately establishing the incidence and importance of agonistic encounters between sexes and size-classes will lead to better insights in tortoise behavior.

6.0 MANAGEMENT RECOMMENDATIONS

1. We recommend that the City Creek Plot and adjacent public lands be included as a portion of the Critical Habitat for the desert tortoise in the northeast Mojave desert. It is vital to protect the City Creek Study Site in its natural condition. During 1989, deterioration of the study area occurred as a result of off-highway vehicle use along the eastern boundary of BLM land, and near the western boundary of the City Creek Study Plot as well. These peripheral activities in turn encourage encroachment and habitat degradation throughout the entire area (e.g., invasion of Russian thistle, *Salsola spp.*). If the site is used to help determine the role of nutrition in the health of tortoises, then management will be required to protect the study site and peripheral agency lands from disturbances by unrestricted recreational and commercial uses.

2. We recommend more prudent collection of tortoise carcasses at all desert tortoise trend plots. Before collection, researchers should ask the question," What do we need the shells for, and what will be their disposition after they are collected?" It might be possible to sample the shells in a given population in such a manner as to answer important questions without depleting potentially important mineral sources for tortoises.

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APPENDIX I: List of habitat patch areas (square meters) at City Creek Study Site, Utah in 1989.*

DUNE	TRANSITION	ROCKY	ROCKY TRANS
2628.5	189.9	73.7	25.1
24.5	39.4	254.4	90.0
53.0	46.2	32.4	198.7
15.0	111.0	30.0	8.1
2.7	44.9	3.7	19.4
54.4	261.0	185.0	62.8
9.5	190.5	12504.5	12.5
2534.8		47.1	
22.7		115.5	
33.5		67.9	
24.0		16.5	
275.9		0.0	
137.4		26.6	
740.6		3.1	
27.9		22.0	
170.6		64.2	
		22.9	
		25.1	
		90.9	
		17.3	
		7.2	
		301.4	
		39.3	
		13.8	
		239.8	
		24.1	
		230.3	
		26.0	
		34.5	
		181.9	
		70.8	
		110.3	
		821.3	
		3.8	
		12.5	
		6.4	
		4.6	
		3.4	
		11.2	
		7.3	
		19.3	
		21.4	
		4.1	
		3.4	
		2.8	
		9.9	
		4.4	
		0.9	
		4.9	
		7.6	
		25.5	
		12.5	
		16.8	
		7.6	
		4.5	
		15.0	
		192.9	

*discrepancies in number of patches between this appendix and Table 2 are based on lumping some patches due to constraints of software.

APPENDIX II: Vegetation List of City Creek Study Plot, St. George, Utah in 1989.
ST. GEORGE, UTAH
WASHINGTON QUADRANGLE: T42S, R15W-S-7, R16W-S-12. ELEV 3200'-3500'.

SPECIES	SYMBOL	KEYED(+OR-)	FIELD OBS TORT USE(+ OR -)	SCAT ANALYSIS TORT USE(+ OR -)	TRACKS
Abronia fragrans	ABFR	+	+	+ (in scat prep)	+
Acamptopappus sphaerocephalus	ACSP(Acamp)	+	-	-	
Ambrosia dumosa	AMDU	+	-	-	
Aristida purpurea	ARPU	+	+ (BDS); - (CC)	+	
Artemesia filifolia	ARFI	+	-	+	
Asclepias sp.	Asclep	-	-	+	
Aster sp.	Aster	-	-	+	
Astragalus sp.	Astrag	-	-	+	
Atriplex canescens	ATCA	+	-	-	
Baccharis sp.	Bacc	-	-	-	
Baileya multiradiata	BAMU	+	-	-	
Baileya pleniradiata	BAPL	+	-	-	
Brickelia sp.	Brick	-	-	-	
Bromus rubens	BRRU	+	+	+	+
Bromus tectorum	BRTE	+	+	+	
Calochotrus nuttallii	CANU	+	-	-	
Carex geyeri	CAGE	+	-	-	
Castilleja linariaefolia	CALI	-	-	-	
Celtis reticulata	CERE	+	-	-	
Ceratoides lanata	CELA	+	-	+	
Chilopsis linearis	CHLI	+	-	-	
Chorizanthe thurberi	CHTH	+	-	-	
Chrysothamnus sp.	Chryso	-	-	-	
Coleogyne ramosissima	CORA	+	+	+	
Cowania mexicana	COME	+	+	+	
Croton californicus	CRCA	+	-	-	+
Cryptantha micrantha	CRMI	+	-	+	+
Cryptantha nevadensis	CRNE	+	+	+	
Datura meteloides	DAME	+	-	-	
Dichelostemma pulchellum	DIPU	+	-	-	
Dithyrea wislizenii	DIWI	+	-	+	
Dudleya sp.	Dudley	-	-	-	
Echinocereus engelmanii	ECEN	+	-	-	
Elymus elymoides	ELEL	+	-	-	
Encelia frutescens	ENFR	+	+	-	
Ephedra nevadensis	EPNE	+	+	+	
Eriastrum eremicum	ERER	+	-	-	
Erigeron divergens	ERDI	+	-	-	
Eriogonum fasciculatum	ERFA	+	-	?+	
Eriogonum inflatum	ERIN	+	-	?+	
Eriogonum maculatum	ERMA	+	-	?+	
Eriogonum nidularum	ERNI	+	-	?+	
Eriogonum thomasii	ERTH	+	-	?+	
Erioneuron pilosum	ERPI	+	-	-	
Eriophyllum wallacei	ERWA	+	+	-	
Erodium cicutarium	ERCI	+	+	+ (flower and seed)	
Euphorbia parryi	EUPA	+	+	-	+
Fallugia paradoxa	FAPA	+	-	-	
Fraxinus anomala	FRAN	+	-	-	
Gilia sp.	Gilia	-	-	+	
Gutierrezia microcephala	Gutt	+	-	+	
Gutierrezia sarothrae	Gutt	+	-	+	
Helianthus anomalus	HEAN	+	+	+	+
Heterotheca villosa	HEVI	+	+	-	
Hilaria rigida	HIRI	+	+ (BDS); - (CC)	+	
Hymenoclea salsola	HYSA	+	-	-	
Hymenopappus filifolius	HYFI	+	+	-	
Juniperus osteosperma	JUOS	+	-	-	

Appendix II (cont.)

SPECIES	SYMBOL	KEYED(+OR-)	FIELD OBS TORT USE(+ OR -)	SCAT ANALYSIS TORT USE(+ OR -)	TRACKS
Krameria parvifolia	KRPA	+	+	+	+
Larrea tridentata	LATR	+	-	-	
Lotus rigidus	LORI	+	+	?+	
Lupinus concinnus	LUCO	+	-	?+	
Mammillaria tetrancistra	MATE	+	-	-	
Mentzelia sp.	Mentz	-	+	-	
Mirabilis sp.	Mirab	-	-	-	
[Moss]	Moss	-	-	+	
Muhlenbergia porteri	MUPO	+	+	+	
Oenothera pallida	OEPA	+	-	+	+
Oenothera sp. (YELLOW FL.)	Oeno	-	-	-	
Opuntia acanthocarpa	OPAC	+	-	-	
Opuntia erinacea	OPER	+	+	-	+
Oryzopsis hymenoides	ORHY	+	+	+	
Palafoxia arida	PAAR	+	-	-	-
Pectocarya recurvata	PERE	+	-	-	
Penstemon ambiguus	PEAM	+	-	?+	
Penstemon eatonii	PEEA	+	-	?+	
Plantago insularis	PLIN	+	-	?+	
Plantago patagonica	PLPA	+	+	?+	
Prosopis pubescens	PRPU	+	-	-	
Prunus fasciculatum	PRFA	+	-	-	
Rhus trilobata	RHTR	+	-	-	
Rumex hymenosepalus	RUHY	+	-	-	
Salazaria mexicana	SAME	+	-	-	
Schismus barbatus	SCBA	+	+	+	
Senecio douglasii	SEDO	+	-	-	
Sporobolus flexuosus	SPFL	+	-	-	
Stephanomeria exigua	STEX	+	+	-	
Stephanomeria tenuifolia	STTE	+	+	-	
Stipa speciosa	STSP	-	-	+	
Tamarix pentandra	TAPE	+	-	-	
Tetradymia spinosa	TESP	+	-	-	
Tridens muticus	TRMU	+	+(BDS); -(CC)	-	
Yucca baccata	YUBA	+	-	?+	
Yucca utahensis	YUUT	+	-	?+	

LEGEND
+=positive identification
-=not positively identified
?+=only genus positively identified

Appendix III: Volume estimates for perennial vegetation (cubic meters) transects at City Creek Study Plot, St. George, Utah in 1989.

PER TRANS 1

SPECIES	VOLUME (SQ M)
ACAMP	0.02157
EPNE	13.47049
Gutt	3.59738
HYSA	0.13590
TOTAL	17.22534

PER TRANS 2

SPECIES	VOLUME (SQ M)
ARFI	0.01014
CORA	6.82318
EPNE	2.36293
GUTT	1.71569
KRPA	0.18327
PRFA	0.00510
TOTAL	11.10031

PER TRANS 3

SPECIES	VOLUME (SQ M)
ARFI	17.22660
EPNE	8.87388
LORI	0.00189
YUUT	0.59541
TOTAL	26.69777

PER TRANS 4

SPECIES	VOLUME (SQ M)
ARFI	5.63921
CORA	0.48708
CRCA	0.03002
EPNE	5.64018
Gutt	0.84225
LORI	0.02928
ORHY	0.01992
PRFA	2.70075
Steph	0.43852
TOTAL	15.82721

PER TRANS 5

SPECIES	VOLUME (SQ M)
CORA	4.06613
CRCA	0.00418
EPNE	5.46235
GUTT	1.27727
HYSA	1.32097
LATR	20.55724
TOTAL	32.68813

PER TRANS 6

SPECIES	VOLUME (SQ M)
ARPU	0.07999
CORA	0.02074
EPNE	0.00215
ERFA	0.04924
GUTT	0.00715
HALA	0.00340
KRPA	0.00409
PRFA	0.03360
Steph	0.00140
TOTAL	0.20175

PER TRANS 7

SPECIES	VOLUME (SQ M)
CORA	0.24951
EPNE	5.90131
Gutt	5.53237
Steph	0.13390
ORHY	0.00294
TOTAL	11.82004

PER TRANS 8

SPECIES	VOLUME (SQ M)
EPNE	4.13933
Gutt	2.19323
kRPA	1.07398
PRFA	0.02305
Steph	0.05031
TOTAL	7.47989

PER TRANS 9

SPECIES	VOLUME (SQ M)
ARFI	7.47906
CRCA	0.10648
EPNE	2.86930
ORHY	0.01349
PRFA	3.62620
Steph	0.16470
YUUT	0.11790
TOTAL	14.37713

PER TRANS 10

SPECIES	VOLUME (SQ M)
ARFI	2.23992
EPNE	11.90637
Gutt	1.29565
Steph	0.00496
YUUT	0.13074
TOTAL	15.57764

PER TRANS 11

SPECIES	VOLUME (SQ M)
CORA	3.03527
ENFR	0.17032
EPNE	0.89418
ERFA	0.28866
Gutt	0.07866
HALA	0.00050
KRPA	0.13857
TOTAL	4.60617

PER TRANS 12

SPECIES	VOLUME(SQ M)
CORA	1.69332
ENFR	0.08668
Gutt	0.86809
KRPA	1.60706
ORHY	0.00002
PRFA	0.85686
TOTAL	5.11203

PER TRANS 13

SPECIES	VOLUIME (SQ M)
BAMU	0.06290
Chryso	0.06573
CORA	2.47844
ENFR	0.10935
ERFA	0.00607
Gutt	0.35847
HYSA	0.53430
KRPA	1.15196
LATR	7.81690
PRFA	5.47954
UNK	0.00072
TOTAL	18.06437

PER TRANS 14

SPECIES	VOLUME(SQ M)
ARFI	5.50358
CRCA	0.02091
EPNE	4.18160
ORHY	0.01224
TOTAL	9.71832

PER TRANS 15

SPECIES	VOLUME (SQ M)
AMDU	0.00358
CORA	2.27911
ENFR	0.41508
EPNE	1.53848
ERFA	0.21160
GUTT	0.62842
KRPA	0.71033
OPER	0.00001
Steph	0.07106
TOTAL	5.85768

Appendix IV: Feeding rates for the tortoises at City Creek plot, Utah: Spring, Summer 1989

Mean rates per tortoise (See data below):

A. Mean bites/hr: 408.41bites/hr (±292.275, n=44)

B. *Mean hrs feeding/foraging day: .72 hrs/day (±.793, n=44)
(*.72hrs feeding/ foraging bout X 1 foraging bout/ feeding day).

C. Mean hrs active/ day: .657 hrs/day (±1.007, n=157).

D. Mean weight dry forage/ bite: .0095 g/bite (±.01, n=20),
2 bites/dry Bromus head, each head weighing .019g.

A. X D. = 3.88 g/hr (408.41bites/hr X .0095 g/bite)=E.
E. X B. = 2.79 g intake/ day (3.88 g/ hr X .72 hrs/day)= F.
F. X 66 days/season = 184.14 g forage / season for each tortoise

G. Mean tortoise weight: 2.41 kg (±.42, n=10).

H. 184.14 g forage/ season /2.41 kg tortoise=76.4 kg fora 76.4 g forage /season / kg of tortoise.
Therefore, for every kg of tortoise, 76.4 g forage /season was theoretically consumed.

To calculate the tortoise feeding rates per ha at City Creek for 1989..
Assume that the density of tortoises on the study plot is 100 adult tortosises/ sq. mi.:
76.4 g forage/season X 100 tortoises/sq. mi. X 1 sq. mi./640 acres x 2.471 acres/1 ha=
11.94 g/ha.

Therefore, the tortoises on the site theoretically consumed 11.94 g of forage /ha in 1989.

FORAGING DATA

FORAGING BOUT	#HRS FORAGING/BOUT	HRS ACTIVE/DAY	# BITES	# BITES/ HR FORAGING
1	0.08	1.67	8	96.00
2	0.38	4.53	41	106.96
3	0.92	1.78	250	272.73
4	0.40	3.33	31	77.50
5	1.58	2.42	197	124.42
6	0.43	1.78	91	210.00
7	4.67	5.38	321	68.79
8	0.38	2.17	4	10.43
9	0.20	0.30	90	450.00
10	0.78	2.70	338	431.49
11	0.02	0.52	12	720.00
12	1.07	1.58	439	411.56
13	1.32	2.33	9	6.84
14	1.05	1.27	614	584.76
15	0.35	0.48	109	311.43
16	0.98	1.62	793	806.44
17	0.07	1.05	50	750.00
18	0.12	4.33	27	231.43
19	0.32	3.58	180	568.42

Appendix IV (cont.)

20	0.80	2.15	219	273.75
21	0.10	2.08	61	610.00
22	0.33	3.83	53	159.00
23	0.88	3.22	919	1040.38
24	1.45	2.23	365	251.72
25	1.13	2.17	574	506.47
26	1.42	3.48	333	235.06
27	0.03	3.17	40	1200.00
28	1.53	2.17	185	120.65
29	0.20	3.28	97	485.00
30	0.47	3.58	265	567.86
31	0.83	1.27	673	807.60
32	0.28	4.05	212	748.24
33	1.18	1.53	171	144.51
34	0.02	1.88	6	360.00
35	0.10	1.75	69	690.00
36	0.02	0.62	6	360.00
37	0.09	0.53	31	338.18
38	1.27	4.05	307	242.37
39	1.57	5.92	321	204.89
40	0.22	2.93	193	890.77
41	0.30	3.83	97	323.33
42	0.32	2.63	41	129.47
43	0.73	2.17	175	238.64
44	1.30	4.40	1044	803.08

* The data for the feeding rates includes only those observations where feeding was always observed. This does not mean that there were no other activities observed during these observation periods..

Appendix V: Food items found in microhistological analysis.

Aristida
Bromus (leaf tissue)
Bromus seed and glume
Eragrostis sp.
grass seed
Muhlenbergia sp.
Oryzopsis sp.
Schismus sp.
Stipa sp.
Artemesia sp.
Astragalus sp.
Cactus
Cactus seed
Camissonia-Oenothera ssp.
Coleogyne sp.
composite
composite seed
Cryptantha sp.
Delphinium sp.
Dithyrea sp.
Ephedra sp.
Erodium sp.
Erodium seed
Eriogonum sp.
Eurotia sp.
flower parts
Gilia sp.
Krameria sp.
Lappula sp.
Lotus-Lupinus spp.
Moss
Penstemon sp.
pod
Plantago sp.
Purshia-Cowania ssp.
Unidentified seed
Unknown forb I
Unknown forb II
Yucca sp.
Arthropod parts
Rock

Appendix VI: Plants collected for nutritional analysis in 1989.

Abronia fragrans
Aristida purpurea
Atriplex canescens
Baileya multiradiata
Bromus rubens
Ceratoides lanata
Ephedra nevadensis
Eriogonum fasciculatum
Eriogonum inflatum
Erioneuron pilosa
Erodium cicutarium
Hilaria rigida
Hymenoclea salsola
Krameria parvifolia
Muhlenbergia porteri
Opuntia erinacea
Oryzopsis hymenoides
Sphaeralcea ambigua

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